THE JULY SCIENTIFIC MONTHLY

EDITED BY J. McKEEN CATTELL

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Culture Methods for Invertebrate Animals. Edited by P. S. GALTSOFF, F. E. LUTZ, P. S. WELCH, J. G. NEEDHAM. xxxii + 590 pp. $4.00. Comstock.

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An autobiography of the director of the Cavendish Laboratory and Master of Trinity College, in which the author discusses his work as well as that of his contemporaries. He writes of his three visits to this country describing his experiences at Princeton, Yale, Harvard and other institutions.

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JULY, 1937

THE METABOLISM OF ALCOHOL IN THE ANIMAL BODY

By Dr. THORNE M. CARPENTER

NUTRITION LABORATORY, CARNEGIE INSTITUTION OF WASHINGTON

In 1913 the Nutrition Laboratory of the Carnegie Institution of Washington proposed a tentative plan for the study of the psychological and neuromuscular effects of alcohol on the one hand and on the other hand for the study of the physiological and the chemical processes occurring in man after the ingestion of alcohol. The part of the program dealing with the effects of alcohol on the psychological and neuromuscular processes has had important contributions made to it by Dodge and Benedict and subsequently by Miles.

From time to time studies have also been made upon the chemical side with respect to the changes in chemical processes when alcohol was ingested. These studies have been continued without regard to the changes in the legal status of the consumption of alcoholic beverages. The use of alcohol in beverages has been world-wide for centuries. Consequently the problem of the chemical transformation of alcohol in the human body is not one solely of national concern. At least one nation, the French, obtains as many calories from alcohol as from protein.

Absorption and Recovery

Another reason for continuing these studies is that alcohol has a number of unique characteristics as a material that can be introduced and transformed in the body in quantities comparable with those of the nutrients generally used, protein, fat and carbohydrates. Alcohol is very rapidly absorbed in the body. The direct determination of the rapidity of its absorption in the human body is extraordinarily difficult because of the problem of recovering the unabsorbed portion, but the rate of absorption of alcohol can readily be determined with animals that can be sacrificed at the end of the period in which the absorption is studied. Although alcoholic beverages are usually taken by mouth, the use of alcohol in enemata has been carried on for many years in medical practice. This method of introduction makes it possible to study the rapidity of absorption because the unabsorbed portion can be recovered by

TABLE 1

Absorption of 7.5 Per Cent. Alcohol Solutions when Introduced into the Rectum of Human Subjects

Subject	Date	Alcohol solution: Volume	Alcohol solution: Weight of alcohol	Period injection retained		Apparent absorption of alcohol
		cc	gm	hrs.	mins.	per cent.
C	Mar. 1..	265	19.9	3	10	99.9
D	Mar. 3..	265	19.9	4	4	100.0
A	Apr. 10..	350	26.3	1	0	98.0
C	Mar. 22..	415	31.1	3	15	99.9
A	Apr. 15..	500	37.5	1	4	87.4
C	Apr. 18..	810	60.8	5	43	99.4

cleansing enemata. In a series of studies conducted at the Nutrition Laboratory, the absorption of alcohol from enemata was found to be extraordinarily rapid. Table 1 shows the results of one series of experiments on the rate of absorption of 7.5 per cent. alcohol solutions when given as enemata to human subjects.

This property of rapidity of absorption brings about a quick distribution of alcohol through the whole body because it is readily diffusible in body tissues and fluids. Alcohol has another unique property in that as long as it is still present in the body it can be identified and recovered and in animals, when the animal is sacrificed, the total amount of alcohol remaining in the whole body can readily be determined. In this respect alcohol is unlike other materials that are commonly consumed because it is not possible, for the most part, to follow the course of the usual three nutrients very readily after they are eaten.

Protein, for example, is almost immediately altered in character so that the original material can not be identified again. Certain types of fats may be identified by their peculiar chemical characteristics. Only one of the sugars, dex-

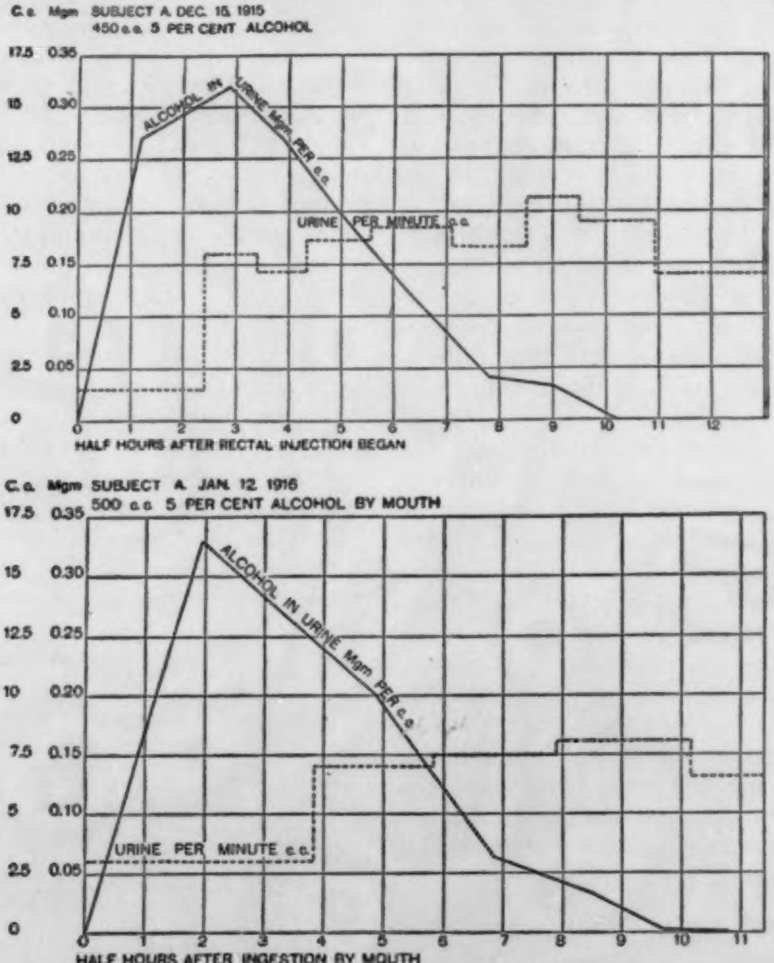


Fig. 1. Curves showing the alcohol per cc of urine at different intervals after the introduction of 450 cc of 5 per cent. alcohol rectally and 500 cc by mouth.

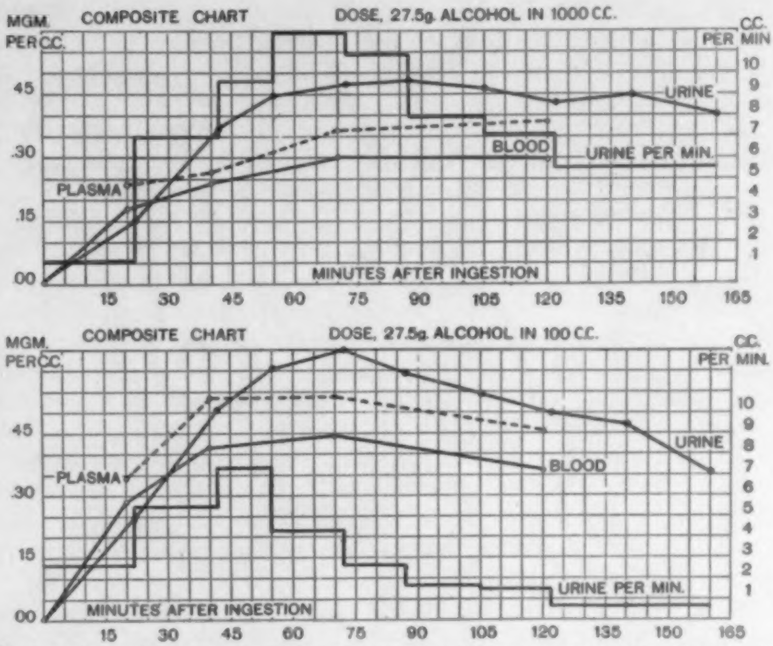


FIG. 2. CHARTS SHOWING THE AMOUNTS OF ALCOHOL IN THE WHOLE BLOOD, PLASMA AND URINE AFTER THE INGESTION OF 27.5 GRAMS OF ALCOHOL IN 1,000 CC AND IN 100 CC OF WATER (AFTER MILES).

trose, can be followed with any degree of certainty, but even in this case it is not known whether the dextrose determined is that actually given, or whether it may not have come from some other source in the body itself so that it is practically a replacement material.

Because of the chemical property of the recoverability of alcohol it is possible to follow the rapidity with which alcohol disappears from the tissues and fluids and thus have an idea of the rate of its transformation. For example, alcohol very quickly appears in the urine after it is once introduced by mouth or rectally. If the urine is collected periodically the alcohol may be determined quantitatively, and the concentration followed from time to time. In Fig. 1 are shown the curves of the concentration of alcohol in the urine after the rectal injection of 470 cc of 5 per cent. alcohol and after the taking of 500 cc of 5 per cent. alcohol by mouth. The maximum concentration was attained in one to one and one-half hours and at the end of five hours there was no longer any alcohol in the urine.

In a similar manner we may follow the alcohol in the blood by withdrawing samples of blood periodically and determining its amount. The alcohol in the blood is parallel to the alcohol in the urine, so that if one has either the urine or the blood the rapidity with which the alcohol is transformed in the body can be followed.

Fig. 2 shows some results obtained by Miles at the Nutrition Laboratory on the comparison between the alcohol in the blood and that in the urine when 27.5 grams of alcohol were given in a dilution of 2.75 per cent. or as 27.5 per cent. alcohol. The dilute alcohol was used because these observations were made at the time that there was an intense interest as to whether this concentration of alcohol was intoxicating. The figure shows definitely the marked parallelism between

the alcohol in the blood and urine and that the alcohol in the urine is always slightly higher than that in the blood, regardless of dilution.

After the ingestion of alcohol it may also be detected in the breath, as is evident to bystanders in the vicinity of any one who has taken a noticeable quantity of alcohol. It should be noted that not only alcohol may give an odor but also other volatile compounds which are present in the liquid in which the alcohol has been taken. It is because of the constant association of these odors with alcohol that we assume that an individual has taken alcohol. Alcohol may, therefore, be determined in a definite volume of the breath and from this, again, is gained a knowledge of the rapidity with which alcohol disappears from the body. Table 2 shows some results obtained by Liljestrand and Linde on a comparison of the alcohol in the expired air with that in the alveolar air, that is, the air in the deepest part of the lungs, and that in the blood. There is a marked parallelism between the alcohol in the blood and that in the expired or alveolar air. In about 2 liters of air, there is the same amount of alcohol as would be found in 1 cc of blood.

TABLE 2

Alcohol in the Expired Air, Alveolar Air and Blood after the Ingestion of 45 Grams of Alcohol Diluted to 150 cc (after Liljestrand and Linde)

After ingestion of alcohol	Alcohol in 2 liters of expired air (31°)	Alcohol in 2 liters of alveolar air (31°)	Alcohol per cc of blood
mins.	mgm	mgm	mgm
10	0.42	...	...
13	...	0.43	...
24	...	...	0.49
27	0.60	...	...
28	...	0.64	...
53	...	...	0.65
56	0.65	...	...
57	...	0.78	...
78	0.65	...	...
79	...	0.73	...
100	...	...	0.67
114	0.53	...	...
116	...	0.53	...
142	0.41	...	...
144	...	0.43	...
153	...	...	0.54
164	0.40	...	...
166	...	0.41	...
185	...	...	0.43
190	0.36	...	...
191	...	0.32	...

These three methods of determining the amount of alcohol present in the body at various intervals after its introduction are of extreme value in determining the rapidity with which alcohol is transformed in the body and how long it still is present.

Respiratory Quotient

Alcohol has another unique property chemically because of the mathematical value of its respiratory quotient when it is completely oxidized in the body. When materials are burned in the body, there is a production of carbon dioxide that is eliminated mostly in the breath and an absorption of oxygen from the air that takes place in the lungs. The volume of carbon dioxide divided by the volume of oxygen in this process is called the *respiratory quotient*. Table 3 shows the respiratory quotients for alcohol and for the three substances which are ordinarily introduced into the body in our food; protein, corresponding to meat, fat of various kinds, and carbohydrates, such as sugars and starch, which are finally transformed into glycogen and stored, when the supply is low or burned. The highest respiratory quotient is obtained with such materials as sugars and starches, and the lowest respiratory quotient under ordinary conditions would be obtained if nothing but fat were burned.

TABLE 3

Respiratory Quotients (R.Q.) and Heat per Gram of Nutrients and Alcohol

	R.Q.	Calories
Protein	0.81	4.40*
Glycogen	1.00	4.20
Fat	0.71	9.50
Alcohol	0.67	7.08

* Heat value when burned in the body.

Ordinarily a mixture of these three substances is burned. The level of the respiratory quotient will be determined primarily by the proportions of carbohydrate and fat that are burned. In the combustion of alcohol, there are two volumes of carbon dioxide given off for three

volumes of oxygen used and the respiratory quotient is 0.67, which is outside the range of the respiratory quotients usually obtained in the burning and transformation of the ordinary foodstuffs used. Also alcohol furnishes energy. The amount per unit of weight is between the amount furnished by fat, the highest, and the amount furnished by starches and sugars, the lowest.

A consideration of these different respiratory quotients shows that if alcohol is burned in large quantities in the body, the respiratory quotient should be lower than when no alcohol is burned. In the study made on alcohol in the urine when alcohol was introduced in two different ways, determinations of the respiratory exchange were also made in order to ascertain whether there was an effect on the respiratory quotient and for the purpose of calculating the amount of alcohol that was burned.

When, however, these results were assembled it was found that although there was a depression in the respiratory quotient, as would be expected, it was not large. The amounts given were such that alcohol disappeared from the urine in about five hours. When calculations were made of the amount of alcohol that was burned, based on the amount of oxygen used and the respiratory quotient on the one hand and on the disappearance of alcohol in the urine on the other hand, there was a discrepancy between the two results. The amount obtained from the respiratory exchange was lower than the amount obtained from a measurement of the alcohol in the urine. Part of the difficulty was the uncertainty as to what kind of materials alcohol replaced when it was burned. The question then arose as to whether there is any particular tissue in the body in which alcohol could be stored and retained.

Distribution in the Body

Therefore a study was made of the distribution of alcohol in the various tissues and organs of the animal body. For this purpose domestic fowls were used, and as alcohol is very readily absorbed from the air in breathing, a system was used in which the animal was placed in a chamber with an atmosphere saturated with alcohol vapor. The animal then inhaled alcohol with each breath, and there was an accumulation of it in the body. The animals were allowed to remain in the chamber for 2 to 29 hours. They were then killed and the various tissues dissected and the amount of alcohol present in each tissue was determined.

It was soon found that these animals absorbed considerable amounts of alcohol in this manner. The amounts remaining in the body at the end of the exposure varied widely, and in general the quantities were proportional to the duration of the exposure, although this was not always strictly true. As a rule the blood had the highest amount of alcohol per unit of weight and those organs that had a large supply of blood, brain, kidneys, spleen, heart, lungs and liver, had alcohol per unit of weight that nearly approached the amount per unit of weight of blood.

Fig. 3 shows the relationship between the amount in the blood and the amount in the liver and that of the whole body and that of the portion called the remainder, namely, that left after the various tissues and organs had been dissected. The two intersecting straight lines within the figure, or the two axes, represent the concentrations. Where these lines cross, the concentration is at zero and extending along the lines in each direction horizontally or vertically the concentration increases according to the scales shown at the bottom and at the left-hand side of the figure. If the amounts of alcohol per unit of weight were the same in all four portions, then the figures would be perfect squares. If on the contrary one tissue had no alcohol in it, the figures would be triangles. In the central portion of this figure for the most part,

three concentrations tend to form two sides of a square, namely, the whole body, the blood and the remainder. On the contrary, that of the liver shows very low alcohol when the rest of the body has also not much alcohol in it, but much lower than the other portions. If, however, the concentration in the blood increases with the different animals, the concentration in the liver tends to approach that of the blood. It is interesting to note that those animals in which the amount of alcohol per unit of weight of the liver was low in relation to the other parts showed no effects of alcohol, thus no signs of intoxication. However, when the liver came to have a concentration somewhat more nearly like that of the blood, then the animals began to show signs of intoxication.

Other relationships of the blood to the other portions of the body are shown in Fig. 4, in which there are included for purposes of comparison the whole body, the skin and the fatty tissues. The fat had extremely small amounts of alcohol per unit of weight in comparison with any other tissue and thus could not serve as a place of storage for alcohol. In fact, from a general survey of the results obtained in this study there is no organ that can store alcohol. The amount present is primarily dependent upon the amount of blood circulating through the particular tissue, although the capacity of the individual tissues to metabolize alcohol undoubtedly also plays a rôle.

It is interesting to note that in some cases the brain had concentrations of alcohol approaching and sometimes even exceeding those of the blood. Also, as these fowls were mature, occasionally

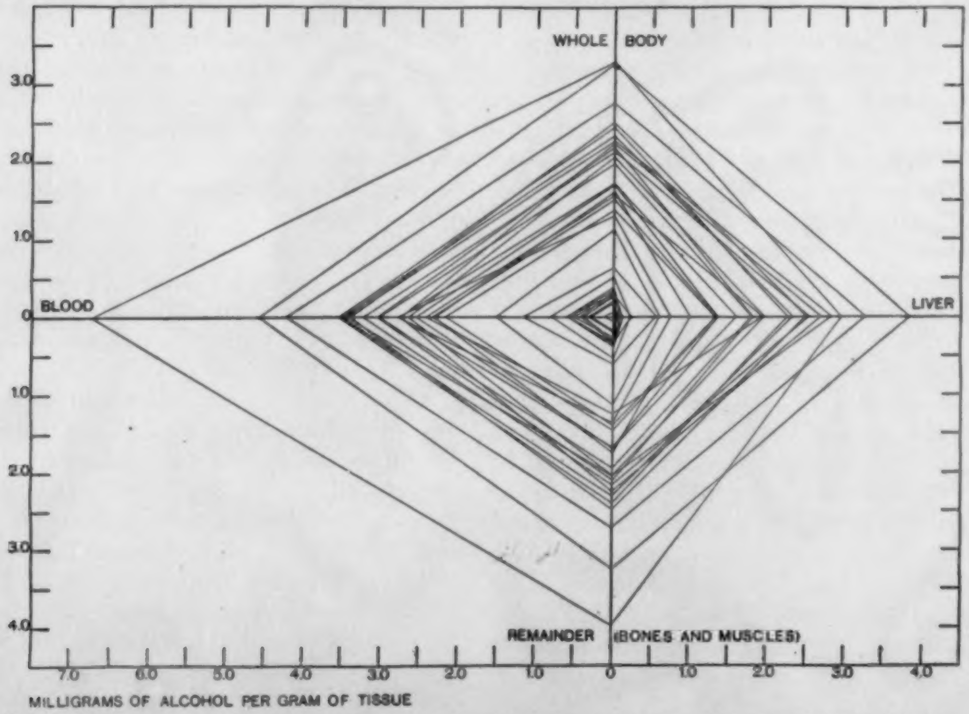


FIG. 3. EQUILIBRIUM POLYGONS FORMED FROM THE PLOTTED CONCENTRATIONS OF ALCOHOL (MILLIGRAMS OF ALCOHOL PER GRAM OF TISSUE) IN THE BLOOD, WHOLE BODY, LIVER AND REMAINDER (BONES AND MUSCLES). ZERO CONCENTRATION IS AT THE INTERSECTION OF THE AXES OF THE FIGURE, AND THE CONCENTRATIONS ARE PLOTTED ALONG THE HORIZONTAL AND VERTICAL AXES. THE POINTS FOR EACH HEN ARE CONNECTED TO FORM A POLYGON.

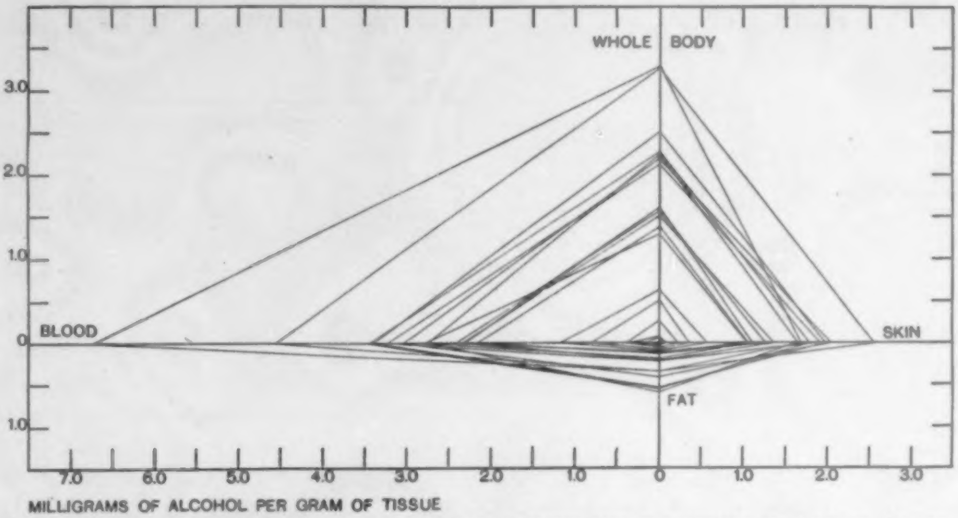


FIG. 4. EQUILIBRIUM POLYGONS FORMED FROM THE PLOTTED CONCENTRATIONS OF ALCOHOL (MILLIGRAMS OF ALCOHOL PER GRAM OF TISSUE) IN THE BLOOD, WHOLE BODY, SKIN AND FAT.

there were present either masses of incompletely formed eggs or even whole eggs with shell on them at the time of killing. Invariably the eggs, even those with shell, showed noticeable amounts of alcohol, even though the time of exposure was short. The nervous system and the reproductive system are two tissues of vast importance for the proper functioning of the body and for the continuation of the race.

Table 4 gives the relation between the concentrations of alcohol in the various tissues and that of the blood. In general the relation is constant, regardless of whether the concentration of the alcohol in the blood is low or high, with the exception of the liver. When the amount of alcohol per unit of blood is below 2.5 mgm the ratio of the alcohol in the liver to that in the blood is much lower than when the amount of alcohol in the blood is above 2.5 mgm. In general this is the dividing line between those animals which showed no intoxication and those that did.

One very important ratio is derivable from this series, namely, the ratio between the concentration of alcohol in the whole body and that of alcohol in the blood, which is about two thirds. If the alcohol in the blood is known, the total amount of alcohol in the whole body can be estimated by multiplying the body weight by two thirds of the concentration of alcohol in the blood. This is of importance for estimating the amount of alcohol not only in animals but also in human beings, as these ratios have been confirmed by several investigators, more particularly by Widmark for humans, so that it is now possible from the analysis of blood to calculate the actual amount of alcohol present through the whole body.

In the study of the distribution of alcohol with fowls a record was kept of the activity during the time of exposure. When these animals were arranged in order of activity it was found that those in which practically no activity was visible showed high concentrations of alcohol, whereas those that had almost continuous activity showed low concentrations of alcohol. It was not known whether these differences between quiet and active animals were due to a possibility that the animals that were quiet had a low capac-

TABLE 4

RATIOS OF CONCENTRATION OF ALCOHOL IN THE VARIOUS TISSUES IN HENS EXPOSED TO ALCOHOL VAPOR

Number of hens	Hours exposed	Concentration in blood	Average ratio of concentration in tissue to concentration in blood											
			Brain	Heart and lungs	Liver	Kidneys	Spleen	Alimentary tract	Skin	Fat	Muscle	Remainder	Eggs (immature)	Whole body*
		mgm												
3 ..	2	0.24	0.8		0.2							0.6†	0.7	0.6
1 ..	3	0.52	0.7		0.2							0.5†	0.3	0.5
4 ..	4	1.76	0.8		0.3							0.7†	0.6	0.7
3 ..	8	2.57	0.8	0.7	0.7	0.7	0.8	0.7	0.6	0.1	0.8	0.6		0.7
6 ..	16	2.17	0.7	0.8	0.7	0.8	0.8	0.8	0.5	0.1	0.8	0.7		0.7
4 ..	29	5.01	0.9	0.8	0.7	0.8	0.7	0.7	0.5	0.1	0.7	0.6		0.6

* Does not include alcohol in feathers.

† Remainder includes the organs not analyzed in addition to the portion usually remaining after dissection.

ity for utilization of alcohol and therefore soon became intoxicated, which naturally would bring about quietness, or whether they were due on the other hand to an actual increased combustion of alcohol as the result of activity. The importance of determining whether alcohol is burned during activity is twofold. In the first place, it would be a contribution to the problem as to the source of energy for muscular work. This problem has engaged the activities of physiologists for many years. Also it would be of practical value in cases where the individual has taken so much alcohol that he has become intoxicated and some means are necessary for restoring him to sobriety. If muscular work increases the combustion of alcohol, the individual ought to exercise.

Effect of Muscular Work

A systematic study of the effect of muscular work on the rapidity of alcohol utilization in the body was made with a human subject. The respiratory exchange was first measured to ascertain whether during muscular work the respiratory quotient would be lower with alcohol than without alcohol. The general procedure was to have the subject rest for one hour during which the base line for the day was measured. Then the solution for the day, either a control or one containing 30 or 50 cc of alcohol, was given him and the measurements were resumed and continued for three hours. On some days these three hours consisted entirely of rest. On other days the subject worked either one-half hour, one hour or two hours and the balance of the three hours was used for a recovery period.

Table 5 gives the excess respiratory quotient during work and recovery on the alcohol and non-alcohol days. By excess is meant the extra amount of carbon dioxide eliminated and extra amount of oxygen used above those that would have been found for the subject had he been at rest the entire time. This gives an indication of the character of the extra material used during muscular work. If, for example, all the work performed had been done with carbohydrate as a source of energy, then the excess respiratory quotient would be 1.00. On the contrary, if the material used on the days on which alcohol was given consisted largely of alcohol then the respiratory quotient would be lower than on the days without alcohol.

In the first group, in which the subject worked for one hour, the excess respiratory quotients on the control days and on the alcohol days were practically the same. In the next group there is only a difference of 0.03 between the control

TABLE 5

RESPIRATORY QUOTIENT OF EXCESS GASEOUS EXCHANGE OF WORK AND RECOVERY WITH AND WITHOUT ALCOHOL (TOTAL PERIOD OF WORK AND RECOVERY, 3 HOURS)

1 hr. 275 kgm p.m. 2 hrs. recovery		½ hr. 550 kgm p.m. 2½ hrs. recovery		2 hrs. 275 kgm p.m. 1 hr. recovery		
Control	50 cc alcohol	Control	50 cc alcohol	Control	30 cc alcohol	50 cc alcohol
0.85	0.85	0.90	0.87	0.84	0.87	0.85
0.86	0.84	0.90	0.87		0.88	
0.85	0.85					

days and the alcohol days. This difference can hardly be considered significant. In the third group, not only is the respiratory quotient on the alcohol days not lower than on the control day but is even higher on the days on which 30 cc of alcohol were given at the beginning of work. This absence of any definite finding of the effect of muscular work and alcohol on the respiratory quotient led to further studies as to the effect of muscular work on the disappearance of alcohol.

The metabolism of alcohol can be studied by determining from time to time the alcohol in the tissues and fluids of the body. In the study on muscular work the urine was collected for the entire period of time of work and of rest following work to ascertain whether, in spite of the absence of any definite result with the respiratory quotient, there would be any evidence that actually there was less alcohol present in the body when muscular work was performed than during rest.

The results are shown in Table 6. With 30 cc of alcohol there was but a slight difference. This difference is within the range of differences that might be found, provided a larger number of experiments were run. In the group with 50 cc of alcohol there are two groups in which the amounts are identical. It is true that the other three columns show slightly lower figures than the rest experiments. However, the general lack of uniformity and definiteness in these results implies that the muscular work has not reduced significantly the amount of alcohol.

TABLE 6

CONCENTRATION OF ALCOHOL IN URINES FOR REST EXPERIMENTS AND EXPERIMENTS DURING MUSCULAR WORK AND RECOVERY (5 TO 6 HOURS) (MILLIGRAMS OF ALCOHOL PER CUBIC CENTIMETER)

30 cc alcohol		50 cc alcohol				
Rest	2 hrs. 275 kgm p.m. 1 hr. recovery	Rest	1 hr. 275 kgm p.m. 2 hrs. recovery	½ hr. 550 kgm p.m. 2½ hrs. recovery	1 hr. rest ½ hr. 550 kgm p.m. 1½ hrs. recovery	2 hrs. 415 kgm p.m. 1 hr. recovery
0.34	0.29	0.75	0.63	0.53	0.75	0.61
0.33	0.30	0.79	0.66	0.59	0.76	0.69

Frequent measurements of the alcohol were then made by determining the alcohol in the ventilating air current of the respiration apparatus. This alcohol must have come from the expired air of the subject. The results with 30 cc of alcohol are given in Table 7. In one group of experiments the subject rested the entire three hours and in the other he worked at the rate of 275 kgm per minute for two hours (equal to level walking about 3 miles per hour) and then rested for one hour. After the third 15-minute period after the ingestion of alcohol there is no significant difference between the amounts of alcohol in the expired air in the two types of experiments. The table shows that in three hours the alcohol has nearly disappeared from the expired air. This would indicate a complete utilization or disappearance either by metabolism or by elimination of this amount of alcohol in that period of time. The utilization of 30 cc in three hours is a rapid rate and is equivalent to 174 calories, nearly 1 calorie per minute. This would nearly equal the energy output of an average man sitting quietly. Because the measurements were not continued until it was absolutely certain that all the alcohol had been utilized, it is diffi-

TABLE 7

CONCENTRATION OF ALCOHOL (MGMS PER LITER) IN EXPIRED AIR IN EXPERIMENTS AFTER THE INGESTION OF 30 CC OF ALCOHOL IN REST EXPERIMENTS AND EXPERIMENTS WITH MUSCULAR WORK (2 HOURS AT 275 KGM PER MINUTE) (15-MINUTE PERIODS)

Kind of experiment	Periods after ingestion											
	1	2	3	4	5	6	7	8	9	10	11	12
Resting experiments ..	0.32	0.20	0.17	0.10	0.10	0.07	0.08	0.05	0.05	0.05	0.03	0.03
	Work periods								Rest periods			
Work experiments	0.17	0.12	0.12	0.10	0.09	0.07	0.06	0.06	0.04	0.02	0.02	0.02

cult to estimate the exact time of the disappearance of this amount of alcohol. In the values recorded in the literature there is rarely, if ever, a value as high as this for the metabolism of alcohol with man.

There were, finally, experiments in which was determined the alcohol in the urine, in the blood and in the expired air. The subject in this case rode an ergometer for one hour after receiving the alcohol. Samples of urine and blood were taken. He then again rode for an hour and the sampling was repeated, and then he rested for two hours. On the rest day the same routine was followed, with the exception that the subject rested the entire time instead of working. In Table 8 are given the results for the blood and urine. The findings on the alcohol in the expired air were essentially the same as in the preceding experiments. There were no significant differences in either blood or urine between the values on the rest day and those on the work day.

TABLE 8

ALCOHOL IN BLOOD AND IN URINE AFTER THE INGESTION OF 50 CC OF ALCOHOL IN RESPIRATION EXPERIMENTS WITH A HUMAN SUBJECT (MILLIGRAMS PER CC)

Kind of experiment	Blood	Urine	Kind of experiment	Blood	Urine
Work at 415 kgm per min.			Rest throughout		
1 hour's work	0.77	0.91	1 hour .	0.67	0.80
1 hour's work	0.48	0.63	1 hour .	0.46	0.60
1½ hours' rest	0.19	0.24	1½ hours	0.26	0.30

The conclusion was drawn that the performance of muscular work after the ingestion of alcohol did not affect the rapidity with which the alcohol disappeared in the body. The only effect muscular work can have on the amount of alcohol in the body is to remove some of it by simple vaporization through the breath. But in these experiments it was found that the actual amount of alcohol removed by the breath during muscular work was only twice as much as that during rest and the maximum percentage of the total alcohol ingested that was removed in any case by the breath was 1.6 per cent. Any attempt to remove alcohol through increased ventilation would require a perfect whirlwind through the lungs in order to be really effective in diminishing the amount of alcohol in the body.

Similarly, the amount removed in the urine was not over 1 per cent. Although it is true that by drinking more water or fluids more alcohol would be eliminated in this manner, the amount that could be removed through flushing would require gallons of water in order to be effective and these large quantities should be taken immediately after taking alcohol, because the amount of alcohol gradually diminishes of itself and there would be no point in taking large quantities of fluids when the alcohol in the body had reached a low point.

It has been found that there is a diminution in the alcohol in the expired air, in the urine and in the blood after its ingestion, but on the other hand we have not been able to ascertain by means of the respiratory exchange or by a study of distribution what has become of the alcohol. The difficulty is in the calculation of the kind of material that alcohol would replace. For this purpose are used the nitrogen in the urine, which represents

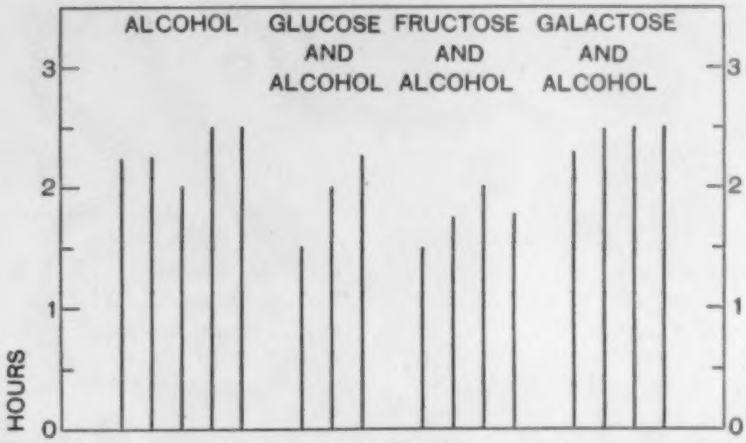


FIG. 5. DURATION OF ALCOHOL IN THE HUMAN EXPIRED AIR AFTER THE INGESTION OF 15 CC OF ALCOHOL ALONE, AND AFTER THE SAME AMOUNT OF ALCOHOL WITH 46.5 GRAMS OF GLUCOSE, FRUCTOSE OR GALACTOSE.

the protein burned, and the respiratory exchange, which represents the sum of the combustion of protein, fat and carbohydrates. When alcohol is also introduced into the body and its effects are added to the respiratory quotient, a situation is produced in which four substances are dealt with and it is not known which of the usual three substances, namely, protein, fat and carbohydrates, alcohol replaces or whether it replaces all three according to their proportions of the amount that is burned at the time of ingestion of alcohol. In all previous work the latter has been assumed. The two materials that have the greatest effect on the respiratory quotient theoretically are the carbohydrates at one end and fat at the other, and in the absence of a marked lowering of the respiratory quotient after the ingestion of alcohol it is conceivable that it is not carbohydrate that is replaced but rather some other substance.

The Effect of Sugars

Mellanby found in his first investigation on the metabolism of alcohol that, when food was ingested along with the alcohol or shortly before the taking of alcohol, there was not so great a rise in the alcohol in the blood as when no food was ingested. At first the effect of food was ascribed to the slowing of the absorption of alcohol. If the effect of food was to slow the absorption of alcohol, we would expect to find that alcohol remained in the body a longer period of time when food was taken than when no food was taken. This, however, is not the case. Some foods actually increase the rapidity with which alcohol disappears.

On the hypothesis that it was not carbohydrate that was being replaced by alcohol but something else, a group of experiments were made in which alcohol was given with and without the addition of sugars. For this purpose there were used the three sugars that occur either naturally or as the result of breaking down of food, namely, glucose, the sugar which occurs in blood, fructose, which occurs in sweet fruits and as a result of the hydrolysis of cane sugar during digestion, and finally galactose, which comes from the splitting of milk sugar during digestion. As pointed out before sugars will raise the respiratory quotient and alcohol should depress it. The problem was whether the sugars would be burned as rapidly when taken with alcohol as without alcohol and what the effect of the sugars was on the disappearance of alcohol in the body.

In Fig. 5 is shown graphically the time during which alcohol was found in the expired air when alcohol alone was given and when alcohol was combined with the three sugars. At the left, the group with alcohol alone shows a longer appearance of alcohol in the expired air than when alcohol was taken with either glucose or fructose. Fructose very definitely hastened the disappearance of alcohol. On the contrary, galactose did not accelerate the disappearance of alcohol.

Fig. 6 shows the comparison between the respiratory quotients obtained when glucose was given alone and those when glucose was given with alcohol. Here there is a very marked contrast between the respiratory quotient after sugar alone and that after alcohol and sugar.

The plan of these experiments was based on the idea that the respiratory exchange should be measured and the alcohol in the expired air determined until the alcohol had disappeared. Corrections could then be made for the alcohol eliminated by way of the expired air and the urine and it could be assumed the remainder of the alcohol had been metabolized in the body, and by metabolized is meant presumably burned. After the respiratory exchange had been corrected for the carbon dioxide and oxygen due to alcohol, the amounts of other materials burned were calculated and a comparison was made of the results obtained on alcohol days with those obtained on the days when no alcohol was given.

When this was done with the experiments with glucose, it was found that we were justified in the hypothesis we started with, namely, that alcohol replaced something else other than carbohydrate. Table 9 shows the changes in the metabolism of carbohydrates and fat after the ingestion of 46.5 grams of glucose and of 15 cc of alcohol, given separately or given together. In the two groups in which alcohol was given there was a marked lowering of the fat metabolism, but there was an increase in carbohydrate combustion whether the glucose was given alone or with alcohol. Alcohol definitely replaced fat in the metabolism.

Referring to the respiratory quotients again and comparing the respiratory quotient of fat (0.71) with that of alco-

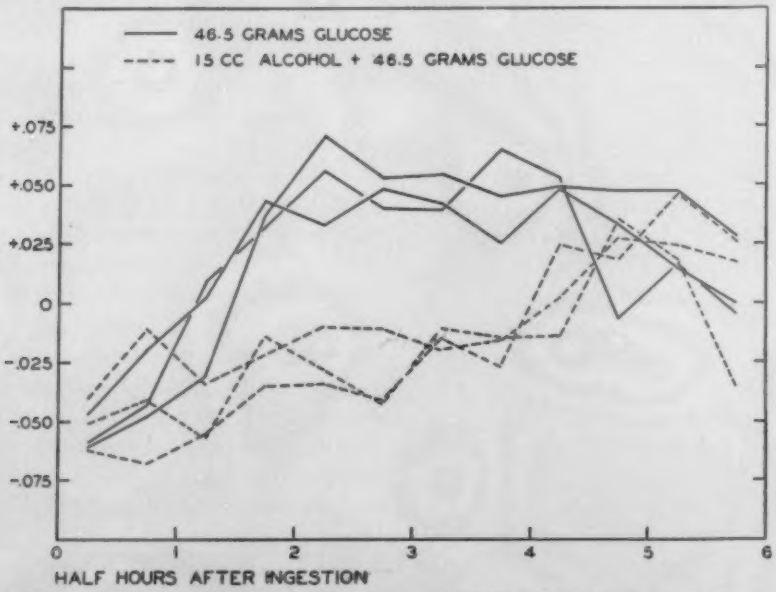


FIG. 6. THE CHANGE IN THE RESPIRATORY QUOTIENT FROM THE PRE-INGESTION LEVEL AFTER THE INGESTION OF 46.5 GRAMS OF GLUCOSE AND AFTER THE INGESTION OF THE SAME AMOUNT OF SUGAR WITH 15 CC OF ALCOHOL.

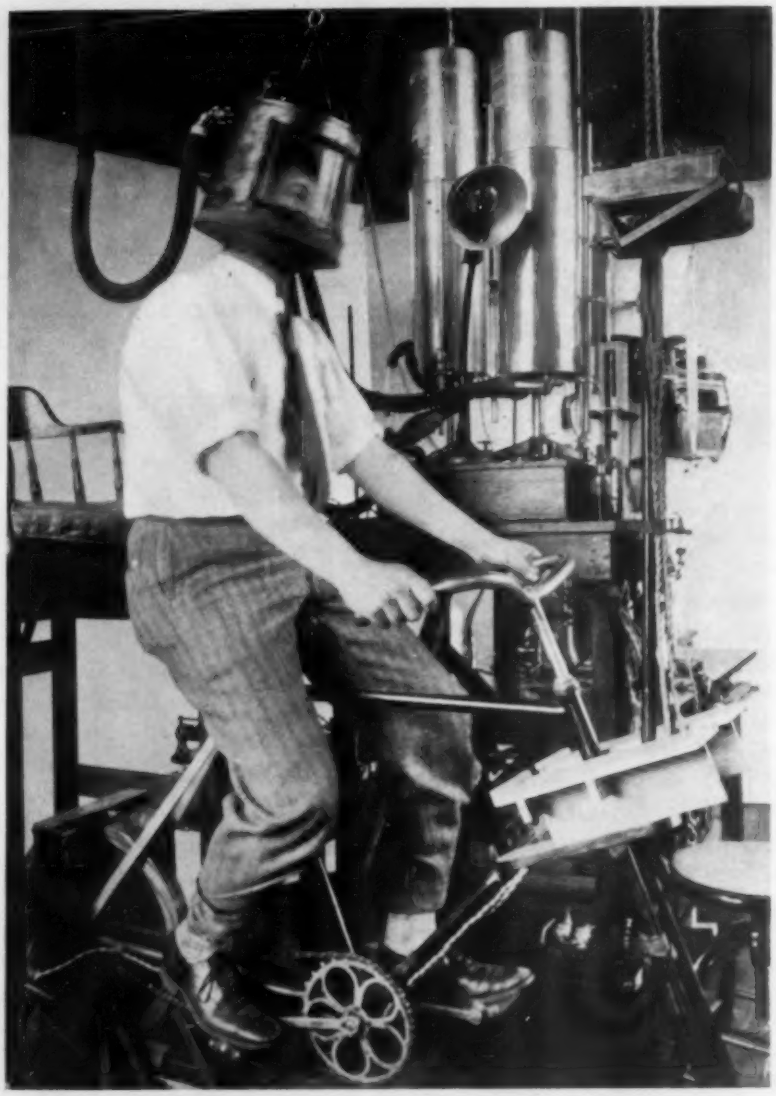


FIG. 7. PHOTOGRAPH OF BENEDICT HELMET RESPIRATION APPARATUS AS USED FOR THE STUDY OF THE RESPIRATORY EXCHANGE DURING MUSCULAR WORK WITH AND WITHOUT THE INGESTION OF ALCOHOL.

hol (0.67), a marked difference is not observable. Therefore, if alcohol replaced fat in the metabolism, the respiratory quotient would not be markedly affected. This seems very definite evidence that alcohol when ingested by man either replaces fat in its combustion or else is converted into some kind of material with a respiratory quotient resembling that of fat.

H. H. Mitchell has recently found that if alcohol is added to a complete diet for rats, there is in the tissue gained by the animals traceable to alcohol a greater amount of fat than is produced from the basic diet alone. Now if alcohol is burned in the body, it furnishes energy, and from the amount ingested a calculation can be made of the proportion of the total energy expended in a given period

TABLE 9
EFFECT OF WATER (CONTROL), ALCOHOL, GLUCOSE, AND GLUCOSE AND ALCOHOL ON THE METABOLISM OF CARBOHYDRATE AND FAT (GRAMS INCREASE (+) OR DECREASE (−) IN THREE HOURS)

	Carbohydrate	Fat
300 cc water	−1.4	+2.2
15 cc alcohol	−2.8	−6.1
46.5 grams glucose	+4.3	−0.7
15 cc alcohol, 46.5 grams glucose	+1.2	−7.6

of time that is supplied by alcohol alone, provided that all the alcohol is metabolized. In the experiments with fructose and glucose the alcohol disappeared from the expired air in most cases at least by the end of the experiment. It therefore seemed justifiable to assume that the alcohol had been burned or metabolized.

When a calculation is made as to what proportion of the energy under these conditions can come from alcohol, we find it relatively high, namely, at least 40 per cent. In a few experiments higher concentrations of alcohol were given along with dry sugar. In these experiments the alcohol disappeared much more rapidly than in the experiments with more dilute solution. In fact, if a calculation is made on the supposition that the duration of alcohol in the expired air represents only the period of time in which alcohol is present in the body, the absurd result is found that over 100 per cent. of the energy can come from alcohol. This points to one conclusion, namely, that instead of the alcohol being burned, the disappearance of alcohol is due to its conversion into some other substance which may either be stored or utilized in the body.

A number of other investigators have been working on the effect of hormones on the rapidity with which alcohol disappears in the body. The most effective one is insulin, a substance that is used in the treatment of diabetes. Very marked increases in the disappearance of alcohol have been found with animals after the injection of insulin. Here again the amounts of alcohol estimated as utilized in the body are so large that it is not reasonable to suppose that they represent actual combustion.

It would seem as though this is one of the lines for future investigation, that is, whether there are any conditions under which the disappearance of alcohol is so rapid that it can not be accounted for solely by combustion. These studies can best be carried on by a combination of methods, namely, measurement in some way of the actual presence of alcohol in the body fluids or expired air and at the same time a measurement of the total respiratory exchange in order to estimate the total energy expended during the entire period of time. The theoretical value of such experiments is great from the standpoint of pure physiology and biochemistry alone, and the practical value of any knowledge of the way in which the disposal of alcohol is brought about in the human body needs no elaboration.

SUMMARY

Alcohol is readily absorbed by the animal body and its presence after absorption can be detected in the blood, urine, and expired air until it has disappeared either by elimination or through metabolic processes. Alcohol is distributed throughout the body mainly according to the blood supply of the various tissues and organs. The disappearance and metabolism of alcohol are not accelerated during increased muscular activity. This conclusion is based on the determinations of respiratory quotients and on the determination of alcohol in blood, urine, and expired air. Studies with sugars and alcohol, in which the respiratory exchange and the alcohol in the expired air were continued until the alcohol had disappeared, showed that alcohol replaced mainly fat in the metabolic processes.

THE STORY OF WHALING

A PARABLE OF SOCIOLOGY[1]

By Dr. JOHAN HJORT

PROFESSOR OF MARINE BIOLOGY, UNIVERSITY OF OSLO, NORWAY

In "Moby Dick" you'll find this charming sentence: "I stuffed a shirt or two into my old carpet-bag, tucked it under my arm, and started for Cape Horn and the Pacific. Quitting the good city of old Manhatto, I duly arrived in New Bedford."

As the intellectual center of the New England coast, where whaling has been an important factor during the three centuries which we are now celebrating, Harvard itself is intimately associated with the history of whaling. In times of expansion, success and prosperity as well as in periods of decline, failure and poverty, whaling was the very first industry on the high seas.

I was very pleasantly surprised to receive the invitation to deliver a lecture on the story of whaling in this center of tradition and at this historical meeting. I beg to accept the invitation as a representative of the Norwegian whalers. It may truly be said of these countrymen of mine, what Herman Melville writes on your own whalers of former days: "Often, adventures which Vancouver dedicates three chapters to, these men accounted unworthy of being set down in the ships common log."

Some years ago a Norwegian captain, somewhere in the Ross Sea, took his floating factory in between two rapidly approaching icebergs to liberate his catchers which had stuck in the ice. "It is nothing to speak of," he said to me. "I saw that my men were in danger and took them out." I was glad at that moment that no personal adventures ever figured in the reports from my own expeditions and believe that I agree with all whalers if I by this occasion confine myself to scientific problems and facts only. But, to quote Herman Melville once more: "If you declare, that whaling has no aesthetically noble associations connected with it, then I am ready to shiver fifty lances with you there, and unhorse you with a split helmet every time."

I was no less pleased to accept this invitation as a biologist. It encouraged me to hope that this great meeting will mark a change in the valuation of scientific ideals—a sign that the aim of scientists will no longer be so predominantly, as hitherto, a flight from the visible and from the practical work of men into the realm of pure thought; a sign that the observation of nature in all its splendor will again be considered intellectually satisfying and a joy of scientists, as it always has been to naive human realists.

The whale is the greatest individual form of existence, of life in nature; one blue whale may weigh as much and more than a thousand men. The whale, therefore, represents the greatest contrast to the invisible particles which for many years have so greatly absorbed the interest of scientists. On the other hand, the activities of man in whaling are interesting not only from a commercial point of view, but as parables of general problems of the greatest importance in modern human societies.

The particular aim of this lecture will be to discuss analogies or correlations which present themselves to scientific thought in the synoptic view of the life of the populations of whales and the exploitation of the stock of whales.

[1] A paper delivered at the Tercentenary Conference of Arts and Sciences at Harvard University, September 8, 1936.

(1) Differentiation

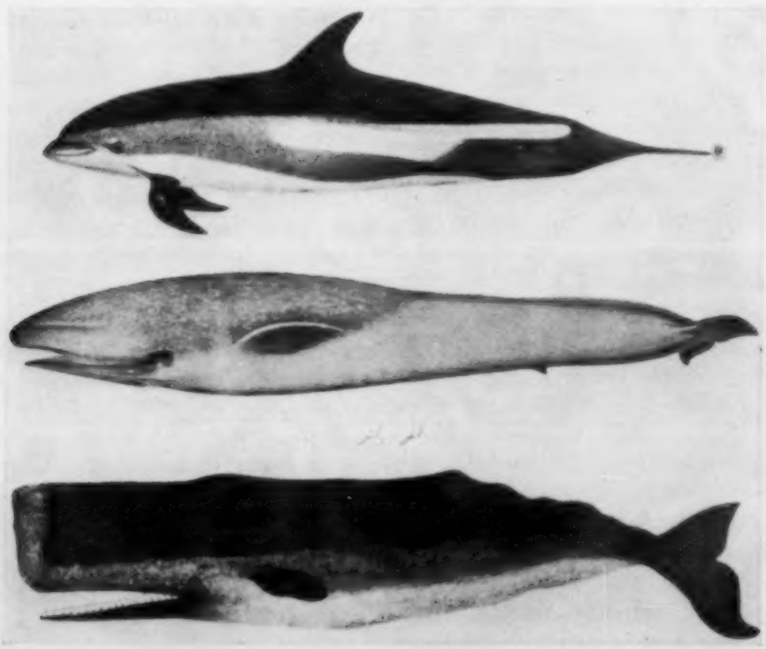
The first and most fundamental analogy between nature and human activities is the parallel of principles which nature applies in her creation of species by differentiation of structures and functions and which man must follow by division of labor in all his enterprise.

This parallel, however, has merely a superficial importance if the differentiation into species or the organization of work by division of labor can not be correlated with certain definite factors which guide the events in a special direction. In biology this synthetical process is called the adaptation to the external conditions of life; in sociology, the adjustment of work to technical and social necessities.

If we remember how difficult it is to make out the details of the organization of the enormous bodies of the whales, and if we remember how scarce the material at the disposal of scientists was in former days, it must be considered a remarkable achievement that the Danish biologist Eschricht as early as in 1846 was able to see the correlation between the specific forms of whales and their adaptation to the different sources of wealth and means of subsistence in the ocean. So he distinguished four biological groups of whales: those which lived on fish, on warm-blooded animals, on crustacea of many kinds and sizes and lastly on cuttlefish.

In this way we realize that each type of animal reflects the potentialities of development afforded by the sea itself. Knowledge of the whales of the past even enables us to understand the conditions which existed in the ocean in bygone days. A speculative branch of science has actually constructed evolutionary series by which these extinct ancestors are linked up with their modern descendants.

In the coastal seas—off the shores where the ancestors of the whales lived—there were shoals of all kinds of fish,



THREE COMMON WHALES

Top: Delphinus acutus photographed in the Bergen Museum. *Middle:* The Blue whale, *Balaenoptera musculus.* From G. O. Sars. *Bottom:* The Sperm whale or cachalot.

Bryn Phot.

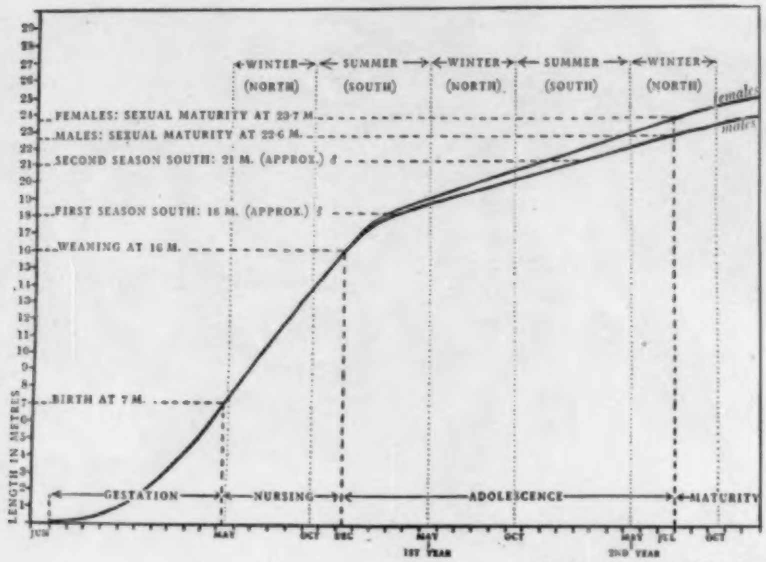
THE ANTARCTIC RIGHT WHALE, *BALAENA AUSTRALIS.*

equal in size to our cod or salmon. These were the fish which tempted the land animals to begin hunting in the sea and turned them into fast swimmers and clever fish-catchers. Nowadays the coastal seas support a great many different kinds of whales, the most numerous groups being the dolphins. These are typical fish-eaters.

But the coastal seas contain other forms of wealth; small fish in such quantities that, taken in bulk, they leave the larger kinds far behind. There are the caplins, herrings, sardines and many other species. And then there are altogether different types of animals—crustacea of innumerable varieties: minute species measuring a few millimeters, which are known as red copepods, and larger sorts, about an inch long, which our fishermen call "krill."

A whale built like a dolphin, with powerful many-toothed jaws, would never survive if it had to live by catching all these little creatures one by one. But common to the life history of all these small species is the peculiarity that they can be caught in a net or bag. Nature made a similar technical invention when she created the grid of the whalebone whales. Of these there are two groups. First, there are the clumsy right whales (genus *Balaena*), like the Nordcaper and the Greenland whale, which skim the sea. The body of the whale pushes as it were its huge mouth through the water, which filters through the high grid of long whalebones, while the small creatures are retained. Then there are the strong, rapid swimmers—the finner whales (genus *Balaenoptera*), which "play," as the whalers call it. No sooner do these whales catch sight of a patch of food than they are upon it in a flash: they take a huge mouthful, say several barrels full, of minute organisms, and then with their powerful tongues squeeze out the water through the natural filter formed by their short whale-bones.

Among the genus *Balaenoptera* nature reaches the greatest units, individual units in existence. The muscles of one blue whale may weigh over 56 tons, its blubber 26, the bones 23, the tongue more than 3 tons and the heart 600 kilos or 1,200 pounds. A new-born blue whale



Mackintosh and Wheeler

THE GROWTH OF THE BLUE WHALE.

has a length of 7 meters or 21 feet and weighs 2 tons or as much as 20 men; 7 months later it reaches a length of 16 meters or 48 feet, 12 months later 23 meters or 69 feet. In the first seven months the whale puts on a weight of 21 tons or 100 kilos or 200 pounds in 24 hours. If a blue whale puts on 10 knots speed it develops about 47 horse-powers. For hours on end I have watched my friends the whalers trying unsuccessfully to overtake a blue whale in the Antarctic waters. Hour after hour the impatient gunner would call for full speed, but though he could steam at 13 or 14 knots he often had to give up, while I felt a thoroughly unbusinesslike admiration for the powers of the whale and marveled at the wonderful machinery that nature has constructed out of flesh and blood.

The first whalebone whales must have chiefly preyed upon small fish, which still play an important part in the diet of certain species, such as the humpback and the finner. As time went on, however, the ocean crustacea acquired increasing importance. And it became increasingly necessary for the whalebone whales to adapt their habits closely to the habits and habitats (areas of distribution) of the animals upon which they lived. If, therefore, we would understand the habits of the whale, we must make ourselves fully acquainted with the life-history of all these animals, which serve as their food.

If we fish with a tow-net in the coastal waters of the Norwegian Sea in wintertime, the resulting catch will be very meager. Tons of water may be filtered without finding more than a few surviving specimens of small crustacea, and the only place where a few scattered krill may be met with is the layer close to the bottom in the fjords and on the coastal banks. In spring, on the contrary, when the sunlight calls forth a rich growth of plants, red copepods appear in such immense quantities that they actually make large patches of red on the sea. Later on in the summer there are swarms of krill. These rise from the bottom layers of water in order to spawn their tiny eggs, which look like minute glass globes, on the surface of the sea.

It is only at such times, when the red copepods, krill or small fishes are present in dense masses, that the whalebone whale can catch enough food to satisfy its enormous requirements. Whaling

operations off the coast of Norway have furnished ample evidence of the connection or correlation existing between the simultaneous appearance of "food animals" and whales. In the north, off the coast of Finmark, several annually recurrent migrations of whales have been observed. Thus in spring (April) the fin whale (*Balaenoptera physalus*) made its appearance exactly at the same time as the vast spawning shoals of a small salmonid, the caplin or "lodde," as our Norwegian fishermen call it (*Mallotus villosus*), arrived on the coast. As soon as the shoals of fishes disappeared, the whales likewise took their departure. Later on in the year, at mid-summer, when an arctic crustacean, a krill (*Thysanoessa inermis*) swarmed in these waters, the big blue whale arrived on the spot for the brief spawning period of this krill. Farther to the south, off the coast of Möre (near the Romsdal fjord), spring is the spawning time of the boreal herring, and also of the arctic krill (*Thysanoessa inermis*), which in the arctic north does not swarm before the summer. The fin whales, however, have accommodated their habits to the spawning periods of these animals. In Finmark they pursue the caplin shoals, while off Möre they prey on the shoals of herring. That this is so may be seen from the whalers' annotations of the places where the fin whales were caught in spring and from the contents of the stomachs of these whales. In summer not the arctic but the boreal species of krill (*Meganyctiphanes norvegica*) swarms on the slopes of the southern coastal banks. On the spawning grounds of this latter species fin whales are caught whose stomachs are one mass of krill. But the connection between the simultaneous appearance of "food animals" and whales is, perhaps, clearest if we take into account what we know of the sei whale (*Balaenoptera borealis*), which lives on very minute crustacea (the copepods), especially *Calanus finmarchicus.* A curve represents the efflorescence and subsequent diminution of these small crustacea, in close correspondence with the appearance and disappearance of the sei whale. The correspondence shows similar regularity on all the coastal banks of the Norwegian Sea and the North Atlantic. It has been found to exist on the slope of the North Sea, the slopes of the Shetlands and Faroe Islands, and off Iceland and Greenland.

This means that the whale must somehow manage to be always in the right place at the right time. How the whales know their away about in the ocean, and how, for instance, they find the slopes of the coastal banks where the krill spawn, is a mystery too deep for mortal man. All that our researches reveal is the connection between the behavior of the animals which serve as food and the arrival and departure of the whales. We can understand, however, how important it must be for the whales to be able to migrate immense distances. At one time the waters of the Norwegian Sea will be richest off Iceland; at another time on the slope of the North Sea bank; or off the Norwegian coastal banks; or—at midsummer—in the Barentz Sea between Finmark and Spitzbergen. The sei whale, which lives mainly on red copepods, must be on the spot wherever the "harvest" is at its height. The finner whale makes for the spawning shoals of spring-herring in winter, and for the spawning swarms of krill on the banks in summer. Thirty years ago harpoons found in whales caught off the coast of Finmark were traced to the whaling industry off the northeast coast of America.

Great, however, as are the distances covered by the whales, their migrations are none the less subject to definite laws and limitations. In these laws and limitations we see again a close connection between the natural conditions and the animals' lives.

No whalebone whale could survive in those immense vasts of the world ocean

STOMACH CONTENT OF WHALES

Upper: STOMACH OF THE FIN WHALE CONTAINING HERRINGS. *Lower:* STOMACH OF A WHALE CONTAINING KRILL.

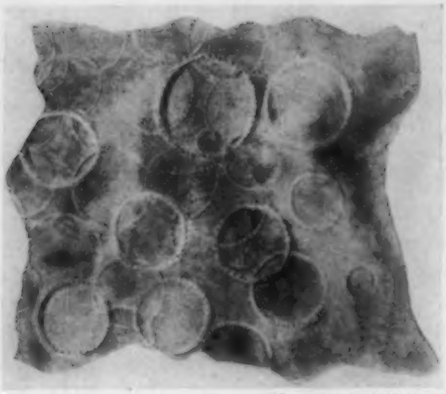
where uniform tropical temperatures prevail all the year round. And the reason is evident at once, if we tow a net in such seas. The forms of animal life which furnish the nutriment of a whalebone whale are only present in very scanty numbers in the clear, transparent blue water of the ocean. It is only in the far north or in the highest southern latitudes, that is, in the parts of the sea which form a transition from the warm to the polar regions, that such a profusion of life develops in the water during the summer. At the present time the science known as general biological oceanography is making strenuous efforts to lay

bare the causes of this complex distribution of the riches of the ocean in so many different parts of it. The key to the riddle has now been found, and the investigators are now busily engaged in demonstrating all the details of the solution. Only in those parts of the sea where the fluctuations of the seasons play a decisive rôle do substances, similar in chemical composition to the manure used in agriculture, rise from the depths to the surface. These stores of nutriment from the depths are responsible for the enormous growth in spring, when the sun returns after the long winter. Biologically, the chief interest naturally attaches to one characteristic feature of the economy of the ocean. This is the fundamental fact that the same natural conditions with the same rich supplies of nutriment for the development of life recur annually in the transitional layers bordering on the polar seas in the south and north; and moreover that both areas, separated though they are by the insurmountable barrier of the tropical seas, foster the same or very closely related organisms, from plants of the simplest structure to the highly developed and complex whales.

In the arctic boreal zone, then, the whalebone whales migrate northward as the spring advances, from the Atlantic Ocean to the coastal waters of Norway, the Barentz Sea and Spitzbergen. In the antarctic summer there is a migration of whalebone whales towards the edge of the ice in the south, moving from 50 to 60 and thence to 70 degrees of southern latitude as the summer advances. After that there is a movement in the opposite direction, towards Australia, Africa or South America when autumn and winter set in the southern hemisphere.

A marked feature of the life of the whalebone whales is, therefore, the alternation of superfluity and famine, of the richest fare and lengthy periods of starvation. In these circumstances their life has been preserved by evolving a capacity to store nourishment, *i.e.*, whale oil, in their bodies. This reserve of nutriment is kept in the muscles, bones and layers of blubber under the skin. The stock is laid in in times of plenty, when the layer of blubber swells to many times its former size; later, in the days of famine, it shrinks until, in many places, it is only one inch thick. These reserves give the whales the energy and stamina which enable them to undertake their enormous migrations; and the layer of blubber also makes it possible for these warm-blooded animals to stay about the ice in water, which is often below 1° Centigrade. This layer of blubber protects the animal from loss of energy and heat and gives it the necessary strength for its strenuous exertions.

Yet a third great group of supplies in the ocean has been discovered by the whales. In all the larger oceanic areas—the Atlantic, Pacific and Indian Oceans—we encounter large herds of immense whales which have found out how to live even in the transparent ocean waters of the tropics. They have, in fact, discovered something which was unknown until the great oceanographic expeditions of recent years, namely, that the world-ocean has a layer several hundred fathoms below the surface, inhabited by abundant life. Here one can catch, with a trawl or a large net, quantities of big shrimps and small fish which in turn sustain an animal population of huge cuttlefish, including the so-called giant squid with a body which may be as much as ten meters in length and arms up to six meters long. To capture these organisms nature has created a special kind of whale, the cachalot or sperm whale, and its relative the bottlenose. These whales are able to dive to great depths—several hundred fathoms—and seize the big cuttlefish in their vast mouths. The great heads of the cachalots are often covered with sores and marks of the suckers of the giant squid, tangible evidence of



Murray and Hjort

SKIN OF A SPERM WHALE

WITH MARKS FROM A STRUGGLE WITH A GIANT SQUID.

battles between the two largest forms of animal life existing to-day. Such fights are everyday occurrences in the depths of the sea.

(2) THE HISTORY OF WHALING

I have dwelt so long with these elementary and important biological facts, because they seem to me as indispensable for the understanding of the material conditions of whaling.

From the knowledge that every species of whale is dependent on certain specific "food-animals" and from the distribution of these food-animals in different parts of the ocean we understand that the word "whaling" must cover quite a number of different industries.

Frank Ballens

A SPERM WHALE CATCHING A GIANT SQUID.

From the interesting history of these whaling industries we may mention three main and all of them very important groups: the catch of the right whales, of the cachalot or sperm whales and last the modern catch of fin whales.

(A) In the northern hemisphere there are or have been two very important species of right whales: the Biscay whale or Nordcaper (*Balaena glacialis*) and the Greenland whale (*Balaena mysticetus*). These two species supplemented each other, in so far as the northern

G. O. Sars

THE ANTARCTIC KRILL, *EUPHAUSIA SUPERBA*.

limit of distribution of the Biscay whale corresponded with the southern limit of the Greenland whale. The latter was a really "arctic" species, the former may be called a boreal species. Perhaps did their area of distribution coincide with different food-animals (species of krill, the arctic *Thysanoessa* and the boreal *Meganyctiphanes*). In the Antarctic Sea there is only one right whale (*Balaena australis*) which seems to correspond very closely, in its form and boreal distribution, to the Biscay whale.

The history of whaling as a big industry and as a real exploitation of the life of the high seas had its origin as early as the eleventh century with the catch of the Biscay whale in the Gulf of Biscay, where there lived, even in these early times, a relatively dense population and where daring fishermen made the great discovery that it was not so dangerous

after all to attack the large right whales swarming in the bay, even from small and primitive boats.

Since this modest beginning the Nordcaper has been hunted over the great area from the Bay of Biscay to north of Norway and from Newfoundland to the coast and bays of New England, where there in Cape Cod Bay in one day (1700) were killed 29 whales.

But as early as about the year 1600 the pursuit of the Greenland whale overshadowed the catch of the Biscay whale in the North Atlantic. It started in the bays of Spitzbergen, transplanted itself along the border of the ice over Jan Mayen to Denmark and Davis Straits and a hundred years ago to the Pacific, where both the important species of right whales played a great rôle in the whaling of these waters.

In the Antarctic there is no species related to the Greenland whale, but the so-called southern right whale (*Balaena australis*) may be considered as identical or very nearly allied to the Biscay whale. Like this one it has a "boreal" distribution. Great fleets pursued it a hundred years ago off the south sea islands, Australia, Tasmania, Kerguelen, the Crozet, St. Paul and Amsterdam.

(B) Sperm whaling appears to have commenced on the New England coast about 1712 and spread rapidly all over the tropical and subtropical parts of the Atlantic. About 1790 the first spermhunter sailed round Cape Horn into the Pacific. From this time sperm-whaling belonged to all the great oceans. The industry reached its height in 1837. The American fleet consisted in 1846 of no less than 729 ships, all whalers, the majority doing sperm-whaling. To Dr. Townsend, of New York, we owe the most valuable and brilliant charts of the fields of operation of this fleet. The study of these charts may lead to the most important discoveries concerning the wealth of the oceans and the migrations of whales.

(C) Both of these modes of hunting were done in sailing vessels. In their open rowing boats the intrepid whalers assailed their vast antagonists with small spears and harpoons. The whale was flensed alongside of the ship, and the blubber usually stored on board until it could be dealt with on land. The rest of the carcass was returned to the sea. This technique could not be employed in hunting the swift, shy and intelligent finner whales. As long as sailing vessels and rowing boats represented the technique of their human enemies on the high seas, the stock of finner whales enjoyed a perpetual close season.

The invention by Svend Foyn of the technique of steamships, guns and explosive shells meant an entirely new departure in whaling. The catch of the fin whales by means of this technique had a very similar course as that of the right whale and sperm whale industries. The whalers moved from one ground to another: from Finmark to Iceland, the Faroe Islands, Ireland, Newfoundland, the coast of Spain and Portugal, in fact, all over the boreal area of the North Atlantic.

Finally they had to move from the North Atlantic area to the South Atlantic, where nature provides the same whales, the same animal food and the same conditions of the sea. The history of all the three main groups of whaling teaches us, therefore, the same course of events: a rapid expansion in all from a starting point to the whole area of distribution of the species and then a rather rapid decline or cessation of the specific whaling activities.

We will now confine our attention to the general conclusions which seem to follow from the study of these important events and more especially consider the last form of whaling, the catch of fin whales, because we in this case are in possession of better and more reliable statistics.

(3) Conclusions

In the first place we must ask: What is the explanation of the general geo-

Dakin

CATCH OF THE RIGHT WHALE FROM OPEN BOATS
"THE FINAL FLURRY" FROM THE ORIGINAL PAINTING BY O. W. BRIERLY, IN THE NATIONAL ART GALLERY. SYDNEY.

graphical expansion so characteristic in all the different industries? Nowhere has whaling succeeded in establishing a permanent equilibrium or a stable industry in a given definite area. To begin with, there has in all cases been a rapid increase until a turning-point was reached, after which there always was an equally rapid decrease ending in a complete stoppage. An indication that this development is taking place is the transfer of whaling expeditions from one whaling ground to another. That this transfer is not to be considered as an emigration of the whales from one area to another seems perfectly clear, if we consider not only the total number of whales caught in a given area, but also the number of whales per catcher. The statistics from the catches of fin whales off the coasts of Spain and Portugal illustrates the fact that the number of whales per boat reached its maximum several years before the total catch did so. In other words, the continued rise in the total number was only rendered possible by the use of increased material, *i.e.*, a larger number of catchers, with the result that the comparatively limited stock perished within a few years. This is, therefore, the general explanation of the main characteristics in the history of all the different whaling industries. The efficiency and the magnitude of whaling operations must not be indefinitely increased but kept at a level corresponding to the reproductive abilities of the stock of whales, if whaling shall ever be made a lasting human activity. Because the stock of whales, *i.e.*, its number of individuals can never be known, the catch, the average catch of the individual unit will have to be considered as the most sensitive barometer of the status of the industry.

From this point of view the Norwegian whalers themselves very early in the history of the Antarctic whaling decided to organize a detailed collection of statistics. Great credit is due to Mr. Sigurd Risting, secretary to the Whalers' Association for a long period of years, for the establishment of this statistical work. At a later date the government's administration (Hvalrådet) succeeded in extending this

work to a statistical service built on day-books from all the expeditions whaling in the Antarctic. This organization has had much assistance from the *Discovery* committee and the valuable work by the *Discovery* expedition under the leadership of Dr. Stanley Kemp. It is therefore now possible to ascertain all the most important facts from the great antarctic whaling. Date and locality of capture, species, sex, length, is reported for each individual whale. Information concerning the reproduction of the stock and the yield of the industrial production is also available in each individual enterprise.

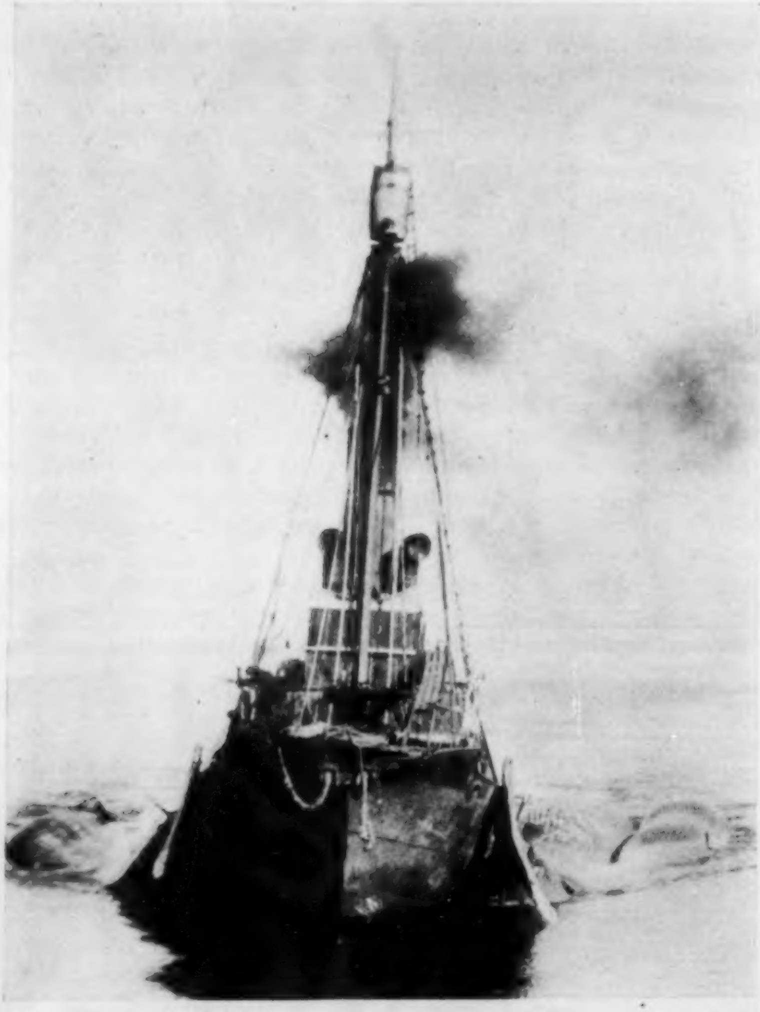
The analysis of this large material, which for every season is published in our reports, will in future form the basis of the history of this industry, and at the same time give valuable information for the understanding of the general problem of the fate of all kinds of human enterprise, which is limited by definite magnitude of wealth in nature. Time permits me no more than the shortest review of the most important historical events.

The modern antarctic whaling started at the Island called South Georgia, in the season 1904–1905. The catch consisted then almost entirely of the humpback whales (*Megaptera boops*) one of the smaller fin whales, which very readily lent itself to be caught by the comparatively primitive technique of those days. This species was then represented by enormous herds. "You couldn't miss one of them," an excited gunner said to me in those days. The species supported the catch most liberally for a number of years, but after 1912–13 this stock had obviously been depleted to such an extent that the whalers had to make a change and start catching fin and blue whales as well. This whaling indicated very remarkable fluctuations in the appearance of the two species, which unquestionably live under dissimilar conditions, the fin being a boreal, the blue whale an arctic species. The whalers themselves realized this many years ago. Thus they spoke of "fin whale years" and "blue whale years," and correlated these alternations with the ice-conditions off the island.

In order to understand the further development we must bear in mind the enormous advance that has been made in

WHALING IN THE FJORDS OF SPITZBERGEN
FROM AN OLD DUTCH PAINTING.

the technical equipment of whaling ships. The earliest expeditions to the Antarctic were planned on the same lines, technically speaking, as those operating in the arctic seas. During the first quarter of the century this technique prevailed in connection with the land stations in the South Georgia and South Shetland Islands. An enormous expansion of whaling followed upon the technical inventions which led to the building of floating factories. Ships of ever-increasing size were constructed or reconstructed until they now are equal to great transatlantic liners (over 20,000 or even 30,000 tons) in order to deal with the carcasses of the whales in the most practical way. The whale is now hauled up through a large opening on to the deck, where a complicated mechanism of winches, saws and cranes quickly cuts it up into pieces to be boiled in large boilers of various types.



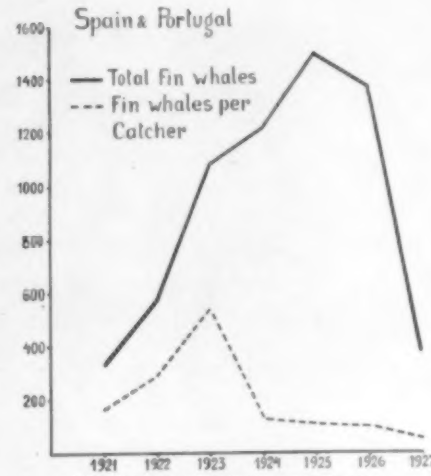
A MODERN CATCHER.

These technical improvements ushered in a new epoch of modern "pelagic" whaling which, like the old right whale

and sperm whale industries, operates on the high seas independently of any base on land. In this way antarctic whaling has spread over the whole Atlantic and part of the Pacific Antarctic Seas. For a series of years our statistical data have demonstrated that the whaling always has taken place along the edge of the steadily receding ice, until at the end of the season, it almost reaches the antarctic continent. Everywhere the whales feed exclusively upon the same species of krill, the ***Euphausia superba.*** During the 36 years from 1886–1904 all the land stations of Finmark caught 17,746 whales, an average of nearly 500 a year; in the Antarctic, where the area covered is immensely wider, the number caught in the season 1930–1931 being more than double the total for the whole period of thirty-six years in Finmark.

For the last thirty years the antarctic whaling has played a great rôle in the life of the population of the southeastern part of Norway, and it is therefore easy to understand that these two questions are being asked and discussed: How long is the whaling going to last and how can we make it last?

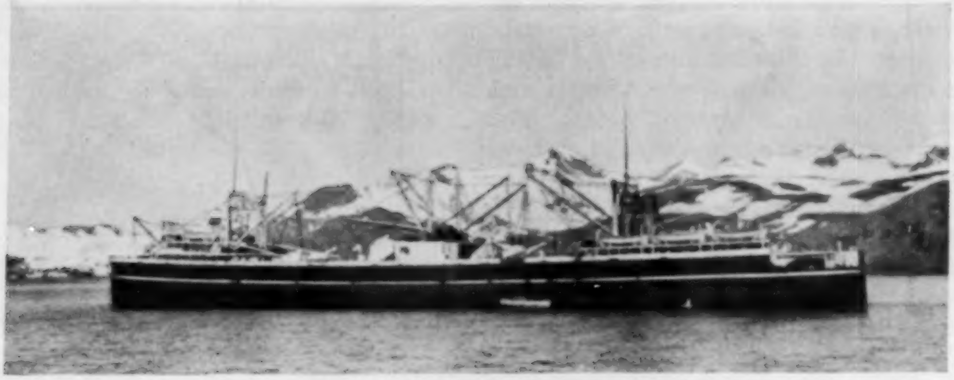
We meet in this discussion the old slogan: trust in the general economical principles and in the principle of rationalization! These principles are certainly and very actively at work. The result of this is that at least 50 per cent. more oil is obtained from each whale than was done in the past. Much capital has been spent by the whalers themselves on experiments on new machinery for converting the flesh and bones into guano or into food for man and beast. But it is obvious that these praiseworthy efforts are not enough in themselves to establish an equilibrium between the whaling industry and the animal renewal of the stock, and nothing but an equilibrium will render possible the continued exploitation of the wealth of the seas or prevent a recurrence of the periodic increase in



NUMBER OF FIN WHALES
CAUGHT OFF THE COASTS OF SPAIN AND PORTUGAL.

whaling activities, succeeded by a decrease and final stoppage. The more valuable the single whale becomes, the further the extermination of the stock is likely to proceed. The fate of the Greenland whale, which rose to such a value

WHALE BEING HAULED ON DECK.



THE MODERN FLOATING FACTORY S. S. "VIKINGEN"
IN THE HARBOR OF S. GEORGIA.

that one single individual was enough to pay all the expenses of an expedition, is a very striking proof of the thesis that the perfecting of methods of capture and preparation affords no solution of the problem of the continuance of whaling. On the contrary, it leads straight to the extirpation of the stock.

Whaling is—in other words—a new and extremely illustrative example of the fact that rationalization is no way to avoid the great Malthusian problem of overpopulation—human activity being ruined by its own growth, by the forces that check development and progress, the forces that obey what Malthus termed "the restrictive law of population." Seen in wider perspective, these events in the whaling industry naturally suggest comparisons with the extensive structure of observations and thought built up during the last few decades with a view to a better understanding of the growth of populations under different conditions of life. If we compare on the one side the two curves for a growing whaling industry and the catch per boat, on the other side the growth of a colony of bacteria and its rate of growth, we understand that the expansive development, which we sometimes name rationalization, sometimes competition, may further the rate of growth or standard of life of the individual up to a point, from which onwards an increase of the active population destroys the industry and lowers the individual standard of life. Rationalization and competition are ideals which are conceived in a time of expansion, but they become irrational and destructive to the welfare of the population if the harmony or correlation between the wealth of nature and the activities of man are forgotten or lost out of sight.

The Norwegian whalers or in any case some of them have been willing to accept these points of view. In 1926, when the great expansion of the pelagic whaling started, a committee proposed that the Norwegian government by law should forbid any expansion, any new expedition which had not obtained the permission of the government to go whaling in the Antarctic, on the condition that such an action would meet with an *international* support. In 1927 at a great conference summoned by the French government to Paris this proposal was tentatively advanced by me as well as by a British representative, but we met with a most emphatical refusal from the side of delegates of several countries.

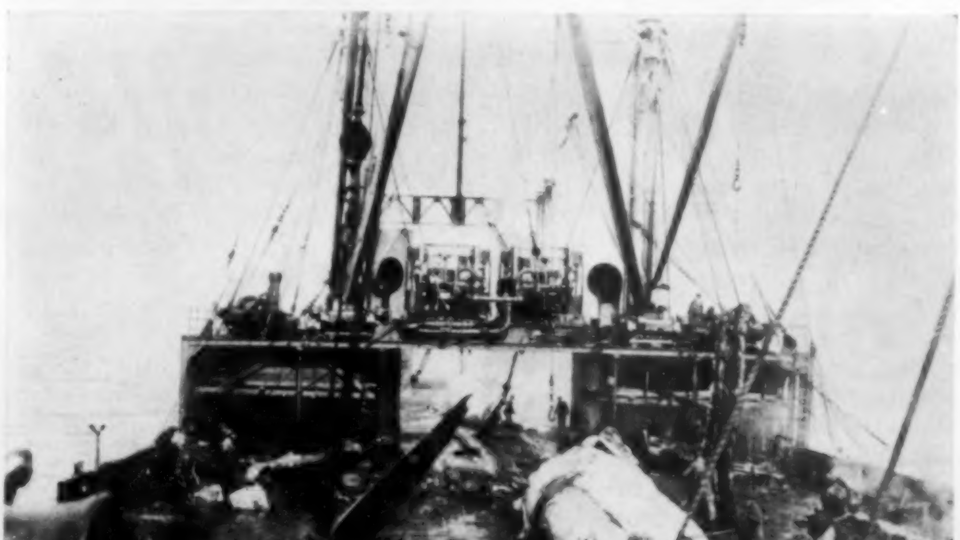
Nevertheless, the Norwegian whalers have for a series of years in coöperation

with the administration tried to establish a constant equilibrium in the catch, and the catch has in this way been kept practically constant at a quantity of some 2. 4 million barrels a year from the year 1932–1933 until now. The means by which this result was obtained have partly been voluntary production agreements or quotas allotted to each expedition, partly a time-limitation of the whaling season, for the last season to three and a half months.

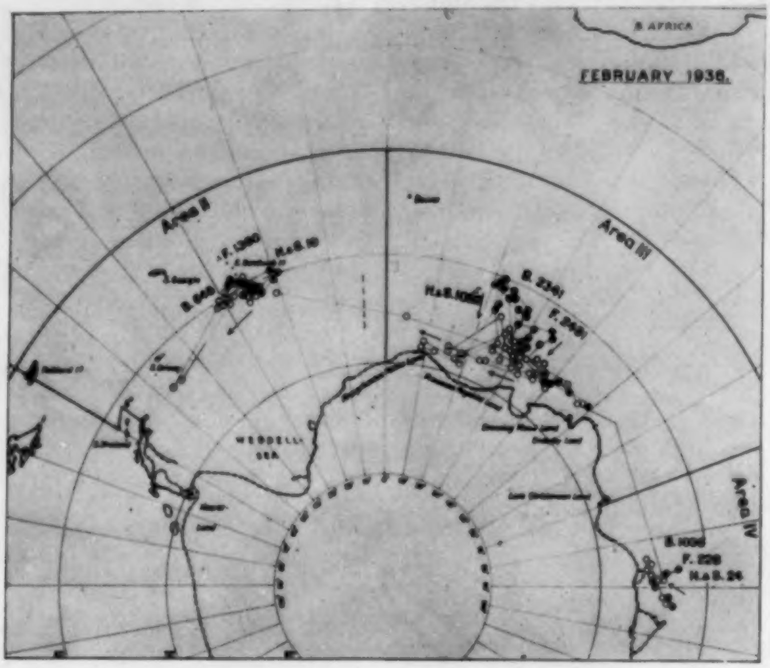
The statistics show that the catch under these conditions has been able to maintain a paying industry if not at a standard of life so high as it was some years ago. The statistics show signs of a decrease of the stock of blue whales, the most valuable species, and that the production has only been maintained by an increased catch of the other, previously neglected species, the fin whale.

The future is therefore certainly full of anxieties. And these anxieties are of the kind which we all know from other expanding international industries. No legislation by the Norwegian government, no self-restriction on the part of the Norwegian whalers can maintain an equilibrium of an industry which assumes an international character.

In all industries there seem to have been two different periods of development. In the beginning the new idea of division of labor creates a long series of discoveries, inventions, all taking the form of an increasing number of plans of division of labor. Later on the original idea seems to lose its fertility. The increase of the number of people taking part of the work is then mostly due to imitation and the application of power or force of conquering the other man's place in the sun. Competition takes at that



WORK ON DECK OF A FLOATING FACTORY.



CATCH OF WHALES IN THE ANTARCTIC
AN EXAMPLE FROM OUR STATISTICS.

stage the form of nationalism, of barriers or national monopoly at the home market while at the same time demanding the retaining of advantages which a liberal world had created.

This has been the fate of Europe, of the old civilized world which once had entered into an international division of labor and tended towards a great common community but now seems to dissolve itself into a system of antagonistic autarchies. Very little hope can under these circumstances be entertained of an international equilibrium of any industry on the free seas, where no organization can be created for an optimum population and an optimum catch.

We must therefore expect either that the industry will establish an equilibrium at a low level determined by the minimum standard of life for the whalers, or that there will be fluctuating periods of successful and unsuccessful whaling corresponding to a slow and incomplete recovery of the stock, similar to what has been seen both in the stock of right whales and of fin whales in areas where the population of whales once were abundant and the industry flourishing.

Is this prospect a parable of the modern international civilization or will ever an idea be discovered not only for the individual but also for an international division of labor?

The fate of the warnings of biology may in our days remind us of that of Cassandra in the Greek tragedy. But the story of past events in the living world may in days to come act its part in the conscious life of society.

CHIMU ARCHEOLOGY

THE ARCHEOLOGY OF THE NORTH COAST OF PERU

By Dr. WENDELL C. BENNETT

ASSISTANT CURATOR OF ANTHROPOLOGY, THE AMERICAN MUSEUM OF NATURAL HISTORY

It was only a hundred years before the coming of the Spaniards that the Incas were sufficiently consolidated and powerful to attack the kingdom of the Chimus on the north coast of Peru. Under the Inca, Pachacutec, 40,000 highland soldiers and auxiliaries from the coast were assembled for the conquest. Even so, according to Philip A. Means, the submission of the Chimus was more the result of fatalistic foresight on the part of their councilors than fear of a superior force of arms. The Chimus themselves had built up a vast empire covering the north coast of Peru from Paramonga to Piura. The great expansion occurred during the late period of the Chimu civilizations, known archeologically as the Late Chimu. Several civilizations preceded the Late Chimu on the north Peru coast, which were intensively developed in their own sections, although more limited in territorial distribution.

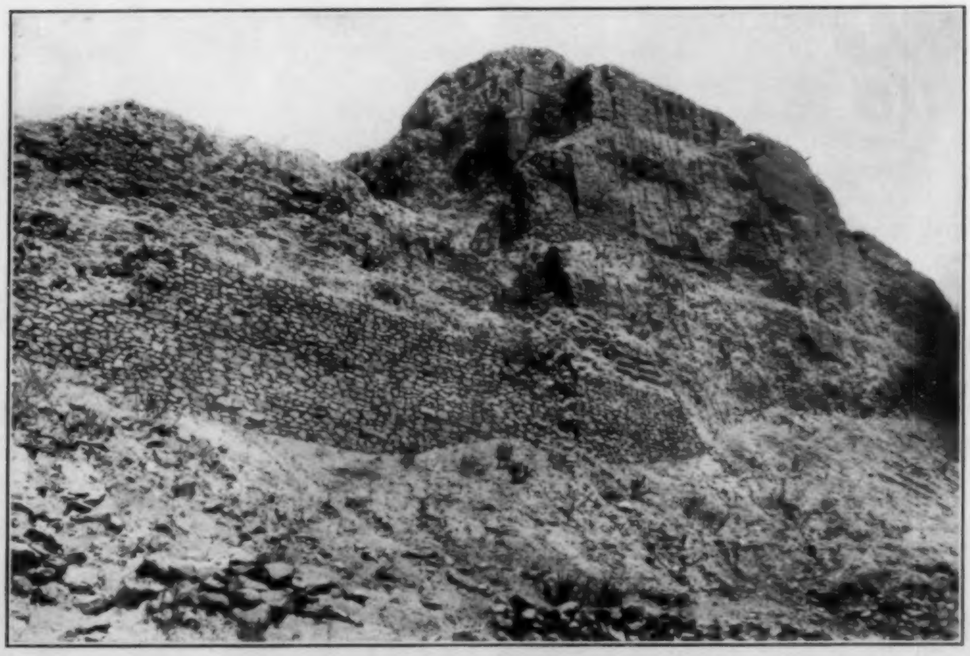
Geographically, the north coast archeological region extends for over four hundred miles along the coast and includes twelve important valleys. From south to north these are Huarmey, Casma, Nepeña, Santa, Viru, Moche, Chicama, Jequetepeque, Saña, Lambayeque, Piura and Chira. In general, the northernmost valleys are larger and better supplied with water. However, only in the Piura and Chira valleys is agriculture able to depend on direct rainfall, while in the other valleys irrigation is required. The cultivation problem in most of the valleys is not one of scarcity of land, but water supply. Although the rivers of seven of the above-named valleys originate in the continental watershed, the supply of water is not constant. In the mountain rainy season, which lasts from January to April, the rivers are apt to be torrential, while during the rest of the year the streams may dry up completely. Between river valleys, and in parts of the unirrigated sections of the valleys themselves, desert conditions prevail. A rough average of 25 to 30 miles of desert separates each valley from its neighbor, and the greatest single stretch of about 100 miles is the desert of Sechura, between Lambayeque and Piura. Compared with the vast stretches of desert and mountain, the coastal valleys are mere ribbon strips. One is particularly impressed by this in flying along the coast. When the trip from valley to valley is made by car, one has a real appreciation of the inter-valley desert areas as factors of isolation. In the northern part of Peru the Andes are not far from the Pacific Coast and spurs and foothills reach the ocean itself. Only in the lower part of a valley is the flood plain of sufficient width to support intensive agriculture. The upper part of the valley passes through narrow gorges which leave only small pockets of flat land for agriculture. The country surrounding the valleys is rugged. The coastal valleys are not only separated by desert stretches but by mountain ridges as well.

This brief sketch of the topography is necessary for an understanding of the archeology. One is impressed by the fact that most of the Peruvian valleys present little enticement to a people without both agriculture and a knowledge of irrigation. Fishing groups could live

along the coast, but fishing peoples seldom develop high civilizations. Only in the northernmost valleys, Lambayeque, Piura and Chira, where the river flow is more permanent, the flood plains wider and direct rainfall more frequent, might the situation be different. In that section, relatively close to the Equator, sufficient forestation and animal life may have existed to attract and support a hunting people, or at least agriculturists with or without knowledge of irrigation. I mention this contrast between the far north and the rest of the coast in anticipation of the archeological analysis which presents some disturbing problems.

Pre-civilization Period

Archeological work has so far presented practically no information about the first inhabitants of the north coast. Remains of relatively primitive fishing populations have been found at Ancon and Supe, just south of this area. However, in spite of the primitive nature of some of this material, there is no proof that it is really older than the remains of some of the higher civilizations of the coast. Fishing hamlets still exist along most of the Peruvian coast, and the life of the fisher is a hard one. Poverty may easily be confused with primitiveness because a poor community might leave few remains for the archeologist. To my knowledge, nothing has been found of great antiquity which is undisputed. No fossil man, no associations with extinct fauna, no artifact deposits in old geological strata and, for that matter, no accumulated refuse deposits of great stratigraphic depth have been reported and confirmed. In other words, evidence either of the development of civilization, or of primitive stages, has not been found on the north coast of Peru up to this time. The oldest civilization on this coast at present is the Early Chimu. To speak of this as the "dawn" would be erroneous. Rather, we might say that the full sun of the Early Chimu suddenly



EARLY CHIMU PYRAMID
OF ADOBES ON PILED STONE FOUNDATION AT EL CASTILLO IN VIRU VALLEY.

DETAIL OF THE EARLY CHIMU FRESCO

AT THE MOON TEMPLE, MOCHE, AFTER A WATER-COLOR REPRODUCTION.

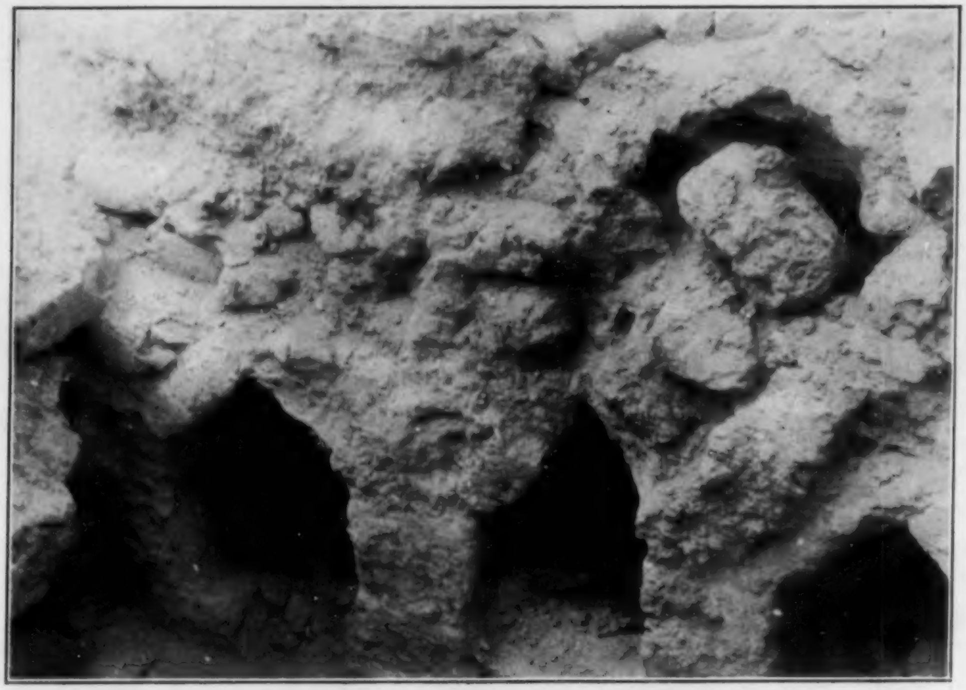
shone on this north coast. Far from being primitive, the Early Chimu or Muchic civilization is one of the most advanced in Peru.

Early Chimu Period

Geographically, the Early Chimu civilization is centered in the Chicama, Moche and Viru valleys. Extensions are found in Jequetepeque Valley to the north, in Santa and perhaps Nepeña to the south, but with less concentration. Further extension along the coast is dubious, although certain similarities may be found in the northern highland region, especially in the Callejón de Huaylas. Means dates the Early Chimu as something B.C. to about 500 A.D. and other authors have more or less accepted this dating. In any case, the Early Chimu can be isolated stratigraphically and typologically as older than other north coast civilizations.

Many large pyramids are attributed to the Early Chimu period. They are identified at some sites (such as El Brujo in Chicama Valley) by their stratigraphic position under secondary buildings of later periods. At other sites the arabesques and mural paintings on the walls are Early Chimu in style, and associated artifacts are likewise consistent. The pyramids are built of adobes, conventionally rectangular in shape and mold made. Adobes of other shapes are also associated with Early Chimu and suggest a possible sequence of types. I have seen adobes of rectangular shape superimposed on hemispherical and on conical shapes. The pyramids themselves are usually high, rectangular, step-sided piles of adobes, and represent some of the largest single structures on the north coast of Peru.

The Pyramids of the Sun and of the Moon at Moche are typical of the Early Chimu structures. Squier gives the measurements of the Sun pyramid as 800



EARLY CHIMU GRAVE IN CHICAMA VALLEY
SHOWING THE NICHES IN THE WALLS OF THE TOMB.

EARLY CHIMU PORTRAIT
FROM VIRU VALLEY.

feet in length, 470 feet in width and about 200 feet in height. It is formed of a great central core of solid adobes with facing layers of adobes around it, forming seven to nine steps. It is an imposing structure, commanding a view of the Moche valley flats. Behind the Sun temple part way up a hill is the Moon temple, also of solid adobes. Painted walls at the Moon temple represent scenes of mythical figures in black, white, red, yellow, light blue, pink and brown. The cemeteries which surround the temples have furnished great quantities of Early Chimu pottery. Early Chimu cemeteries are also found without pyramid associations. Burials are usually in extended positions, in prepared tombs. The rectangular, adobe-lined and covered tombs have niches in their walls in which bowls were placed.

The Early Chimu pottery is characterized by realistic modeling and painted scenes. Jars in the form of modeled heads are so excellently made that they

VESSELS DECORATED WITH "NEGATIVE" DESIGN.
MIDDLE CHIMU WHISTLING JAR, AND OWL JAR FROM VIRU VALLEY.

are reasonably called "portrait jars." Other jars are modeled to represent houses and temples. Small square houses with peaked roofs are typical, which seems strange for a region which experiences direct rain in any quantity about once in every thirty-five years. In the painted scenes are represented deer hunting, battles, fishing, dancing, weaving and many other aspects of life. In fact, a careful analysis of the pottery designs is in reality an ethnography of the Early Chimu peoples.

The archeologist is tempted to diverge into the field of art in his study of the Early Chimu pottery. As an artistic achievement the ceramics of the Early Chimu period are outstanding in Peru and, for that matter, in America. However, from the point of view of the chronology of north coast civilizations, the varied ceramic designs of the Early Chimu period must be treated as a unit. In spite of tremendous collections of this

EARLY CHIMU FIGURE JAR
WITH STIRRUP-SPOUT, VIRU VALLEY.

material in museums there is a dearth of documentary evidence on excavation. The collections made by Dr. Max Uhle at Moche and now in the University of California are exceptions. Still, they do not furnish the basis for subdivisions of the Early Chimu period. The range of style and the change of form suggest that phases, at least, of Early Chimu will one day be isolated, but, as yet, no significant work has been published and so the material is still a large, but none the less, single unit.

modeled face on the collar and a tube spout bowl with a round arc handle.

Middle Chimu

Between the Early Chimu with its realistically decorated pottery and the Late Chimu, which persisted into Inca times, a gap was recognized by most excavators or collectors even before the intermediate stages had been discovered. The contrasts between the two periods are great, in spite of certain basic similarities. In other words, it appears that the Early Chimu civilization went into a period of decline or was supplanted for a time by foreign invaders. The typical Early Chimu disappeared, never to reemerge in the same form, although the influence of its art and certain of its pottery shapes survived to form part of the Late Chimu. Evidence of influence from the south of Peru is undeniable in the Late Chimu pottery, which augments the idea of invasion with or without the accompanying decline of Early Chimu itself.

MIDDLE CHIMU JARS FROM VIRU VALLEY.
THE STIRRUP-SPOUT IS EVIDENCE OF EARLY CHIMU INFLUENCE.

Typical colors of the Early Chimu pottery are red and white, which is quite a contrast to the array of colors used on the wall painting at the Moon temple. A so-called stirrup-spout, composed of two tubes which form an arch and meet in a single tube, is characteristic and is found on modeled heads, figures, animals, birds, reptiles, fruits, vegetables and painted containers of various forms. Other type shapes are a flaring-sided bowl like a flower pot, a conical-handled dipper, a high collar bowl with or without a

VESSELS OF THE MIDDLE CHIMU PERIOD FROM VIRU VALLEY.
LEFT: A DOUBLE-JAR WITH "NEGATIVE" DESIGN. RIGHT: A FACE-COLLAR PLAIN BOWL.

In my excavations during the first eight months of 1936 in Viru Valley I worked for some time at a site on Carmelo Hacienda. Here, in the pyramids of the Gallinazo group, I found a new type of pottery which showed some influence of Early Chimu, had many distinctive characteristics and was definitely not Late Chimu. In other words, the site, a unit in itself, represents an intermediate period or a Middle Chimu. Four medium-sized pyramids are roughly aligned, but not connected. On the platforms of these pyramids are the foundations of old house sites, which furnish house refuse material and a few burials when excavated. Near one pyramid are two small mounds filled with burials. The burials are not in prepared tombs, but are placed directly in the ground, some in a

MIDDLE CHIMU DIPPER DECORATED IN "NEGATIVE" DESIGN,
REPRESENTING A CARRY-OVER SHAPE FROM THE EARLY CHIMU PERIOD FROM VIRU VALLEY.

flexed and some in an extended position. The adobe bricks used in building the pyramids are about the same size and shape as the Early Chimu, but their edges are marked with the impressions of a reed mold.

The pottery is inferior to the Early Chimu, but still shows its influence. A modeled figure bowl with stirrup-spout is represented as well as other vessels with stirrup-spouts. A conical-handled dipper, a high collar jar with modeled

BLACKWARE,
STIRRUP-SPOUT VESSEL OF "CHAVIN" TYPE IN THE NATIONAL MUSEUM OF LIMA.

face on the collar and various other shapes are clearly related to the Early Chimu. In addition are globular bowls with lugs attached which represent bird heads, wings and tails; bowls with conical spouts connected by round bridges to modeled bird heads; double bowls with modeled figures; and various others which are never found in the Early Chimu. Of more importance is the fact that the typical red and white colors of the Early Chimu are not used on this pottery. Although many bowls are not painted at all, others are decorated with "negative" design. In "negative" painting a design is applied to the bowl in wax or some other dye or paint-resisting material. Then the whole bowl is dipped in black coloring. When it is fired the wax runs off, leaving a design in the base clay color on a black background.

The presence of negative design as a characteristic of this pottery suggests contact with another region. In the highland part of the Santa Valley is the Callejón de Huaylas. The remains from that section are distinct from the coast materials. Negative painting is characteristic, particularly at the site of Recuay. Shapes similar to some of those which I found in the Middle Chimu site in Viru Valley occur in this highland pottery. In other words, the Viru site seems to represent a migration, or at least a strong influence, from the Recuay-type civilization. This, mixed with a decadent Early Chimu, would account for most of the Viru site material, and the residue might well be attributed to local development, since the four pyramids and the numerous dwelling sites indicate that it was well established there.

The distribution of this Middle Chimu civilization is not accurately known, and, to my knowledge, the Viru site represents its first isolation. If "negative" designed pieces be considered as typifying it, we may note that they have been found in Santa, Viru, Moche and Chicama, or more or less over all the Early Chimu region.

In the highlands, in the general region of the Callejón de Huaylas, is the famed site of Chavín de Huántar, noted for its amazing stone carving. On the coast of Peru, principally in Chicama Valley, have been found polished blackware bowls with thick stirrup-spouts which are decorated with incised designs compar-

LAMBAYEQUE VALLEY POTTERY.
LEFT: INCA POTTERY. RIGHT: "CURSIVE" STYLE VESSEL.

able to the stone carved designs of Chavín. Their position in relation to the Early Chimu is still questionable, and many consider them as belonging to a preceding period. It seems more probable to me that the Chavín stone carving designs were brought in and applied to pottery by the same peoples or influence which created the Middle Chimu of my Viru site.

OTHER MIDDLE PERIODS

The Middle Chimu, just described, represents a recent discovery, but other influences and periods which fall into this interim between the Early and Late Chimu are known from the work of other archeologists. At Pachacamac and other sites on the central coast of Peru, around Lima, one of the earliest periods represented is the Tiahuanaco. The Tiahuanaco site itself is located in the highlands of Bolivia, but the civilization spread to the coast, forming a secondary center on the central coast. From there it spread both to the south and to the north. In the course of this expansion it incorporated many new elements from the civilizations with which it came in contact, notably the Nazca civilization on the south coast, the result of which is really a new style characterized by the use of

POTTERY FROM VIRU VALLEY.
LEFT: BLACK, WHITE, RED POTTERY. RIGHT: A BLACKWARE PLATE AND A BLACK, WHITE, RED FLASK FOUND IN THE SAME GRAVE.

SECTION OF THE CITY OF CHANCHAN, NEAR TRUJILLO, PERU.
LATE CHIMU CITY WITH PYRAMIDS, BUILDINGS, AND COURTS WITHIN WALLED UNITS.

black, white and red design colors for pottery. The excavations of Dr. Uhle, confirmed by the analysis of Dr. Kroeber, isolated graves of this Tiahuanaco-influenced black, white and red pottery at Moche. They demonstrated that this type of pottery occurred after the Early Chimu and before the Late Chimu periods.

In Viru Valley I excavated a mound which represented a habitation site of the Early Chimu period. Intrusive in this site were graves containing pottery of the black, white and red type, and also considerable blackware. Shapes and other characteristics serve to demonstrate that the blackware and the black, white and red are contemporaneous at this site and form a unit. In spite of the high percentage of blackware, a Late Chimu characteristic, this grave material is not typical of the Late period. Similar sites have been found elsewhere.

The contact of the black, white and red material from the central coast with the Middle Chimu-style already established in the Viru Valley and others, gave rise to a great variety of minor styles. Thus, at the sites of Chanchan and Moche, Kroeber distinguishes a black, white, red; a black, white, red, Recuoid; a cursive; and a cursive tripod. All these styles may never be isolated as separate phases or periods, but they represent the varied strains of influence that interrupted the Early Chimu and brought in the elements known to comprise the Late Chimu.

Late Chimu

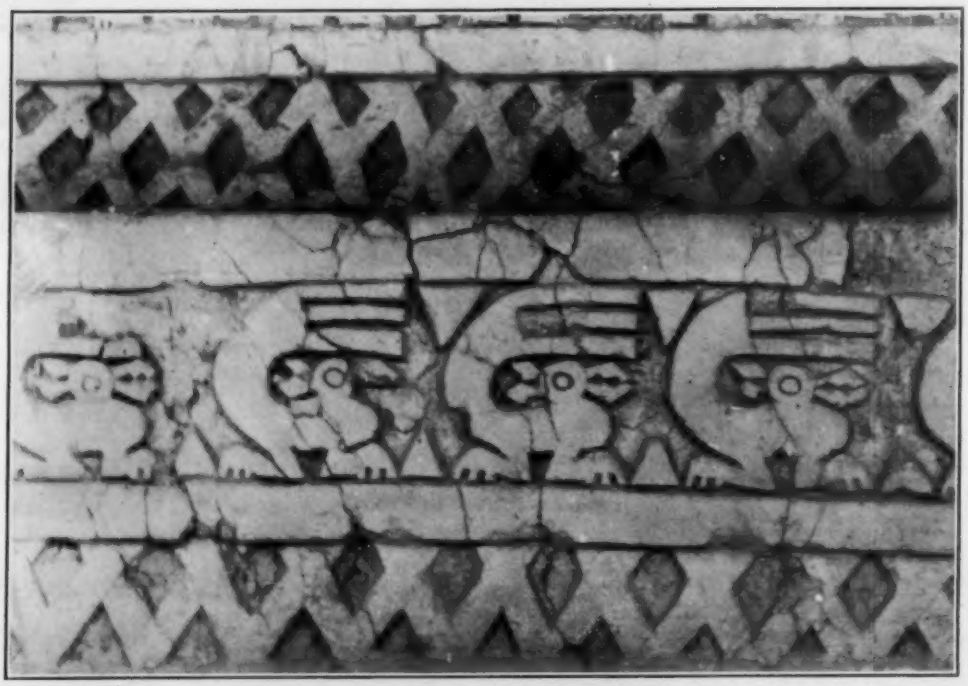
Out of the complex influences of the Middle periods, together with a revival of the dormant Early Chimu, came the Late Chimu. As a period, it represents a new era of autonomy, with little, if any, influence from outside regions. Characteristic is the emphasis on blackware. Less and less attention is paid to painted design, and the modeled and mold-made pottery is smoked in firing to a rich black color. The stirrup-spout of the Early Chimu period is again used with frequency, but it is roughly rectangular in cross-section instead of being round as before, and at the base is added a small modeled lug in the form of a bird or monkey. Double-spouted vessels are common, brought up the coast with the black, white, red pottery from the Nazca region. Double bowls, generally with whistles, are typical. Most of the forms can be derived from the preceding periods, but there are new elements as well. Burials are flexed, usually in a seated position, in graves rather than prepared tombs.

Starting in the Middle periods and continuing with great concentration in the Late Chimu is a new building era. Great cities are constructed in which pyramids are incorporated but are not distinct units. The great city of Chanchan is typical, covering about eleven square miles with a maze of walls, reservoirs, buildings, temples, gardens and cemeteries. Relief arabesques of fine figure designs adorn the walls. The adobes are either small square blocks or long rectangles, and a puddled clay wall, called *tapia*, is also common.

Great pressure for expansion develops in the Late Chimu period. Irrigation projects which open up new tracts of land are carried out successfully. Small quebradas at the edges of valleys are utilized. Furthermore, the expansion includes valleys to the north that were but sparsely settled, if at all, in previous periods. The Late Chimu period concentrates in Lambayeque Valley, where ruins of great size are numerous. The "Purgatorio" city ruin in Lambayeque is in some ways as impressive as Chanchan, although smaller in actual extent. At the time of its maximum expansion, the Late Chimu covered the full four hundred mile stretch of the north coast from Chira and Piura valleys in the north to Paramonga in the south. The great cities in themselves imply a well-integrated social organization, as it has

been estimated that about 200,000 people lived in Chanchan alone.

The Late Chimu peoples were conquered by the Incas in the fifteenth century, but little change in materials is noticed. The type ceramics continue more or less the same, with the addition of a few Inca forms. The polychrome Inca pottery shapes are copied in the Late Chimu blackware, and in other artifacts slight Inca influence is in evidence.



'LATE CHIMU WALL ARABESQUE

FROM A TEMPLE AT THE QUINTA ESMERALDAS NEAR TRUJILLO, PERU.

The Late Chimu-Inca civilization continued for some time after the coming of the Spaniards. Typical Late Chimu pottery is found with decorations in a Spanish glaze. Textiles made by the Indians with the same materials and the same looms as before incorporate Spanish elements in the design.

One problem stands out prominently amongst a myriad others in this résumé of major civilization changes on the north coast. Lambayeque and Piura represent two of the most favorable valleys in Peru to-day, from the point of view of extent of land and the abundance of water. That they were also favorable in pre-Spanish times is witnessed by the extensive irrigation systems and the vast number of ruins found there. The ruins, however, represent, at best, the Middle periods and predominantly the Late Chimu and Inca periods. In the vast collections of pottery made in those valleys hardly a piece can be unquestionably identified as Early Chimu. Furthermore, there is no group of pottery which can not be explained as an influence from the south or a local development therefrom. In other words, in two of the finest valleys of the Peruvian coast nothing has appeared which can be called contemporaneous with the Early Chimu of Chicama and Moche valleys. It is, of course, possible that more excavation will reveal new types, but considerable work

LATE CHIMU MUMMY BUNDLE

PARTIALLY UNWRAPPED, WITH THE POTTERY FOUND WITH IT. VIRU VALLEY.

has already been done, especially by local collectors. One explanation is that such fertile and well-watered valleys were so overgrown in Early Chimu times as to support hunting populations and discouraged agricultural expansion until

TWO LATE CHIMU BLACKWARE DOUBLE WHISTLING JARS FROM CHICAMA VALLEY.

LATE CHIMU POTTERY.
LEFT: A BLACKWARE FLASK FROM LAMBAYEQUE. RIGHT: VARIANT TYPE OF BLACKWARE BOWL WITH STIRRUP-SPOUT FROM VIRU VALLEY.

population pressure demanded it. However, the problem remains unsolved. Furthermore, if migrations came from the north and followed down the coast into Peru, why were these valleys missed?

In order to reduce the archeological history of a region to a few pages of text, elaboration of detail must be neglected and rather categoric statements made. The picture of the north coast given here touches briefly the major periods which are part of the published record to-day. For convenience a résumé of the periods is given in conclusion.

RÉSUMÉ OF PERIODS ON NORTH COAST

Pre-civilization period as yet unknown.

Early Chimu Period:
Well-developed art and artifacts. Subdivisions of this period will probably be isolated, but as yet it must be treated as a unit.

Middle Chimu Period:
A combination of a highland type from the Callejón de Huaylas region and a decadent Early Chimu.

Black, White, Red Period:
Influence from the central coast of Peru moves north creating, at best, a brief period and soon mixing with Middle Chimu to form numerous local styles.

Late Chimu Period:
A north coast development of all Middle Periods plus a revival of Early Chimu influence, with a characteristic smoked blackware pottery.

Inca Period:
The Inca civilization from Cuzco conquers the north coast in the fifteenth century.

Spanish Period:
The Spaniards arrive in the sixteenth century.

PHYSICS AND METAPHYSICS

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THE word "metaphysics" indicates by its derivation that its subject is beyond physics, beyond the inquiry of scientific method. What possible bearing on questions of metaphysics can then have the progress of modern science? The answer is that there arises, once in a while, a border dispute between these two spheres of human thought, each claiming a province for itself. If science gets the better of the argument, then a larger or smaller portion of that primeval forest which is philosophy is cut down, cleared, divided into fields and turned over to the several branches of science to be tilled. Circumstances of this sort arose during the last few years when the discoveries of physics brought a thorough revision of the "Law of Causality." The general reader has no difficulty in getting at the facts in so far as they concern science. Many articles and books written on the subject sufficiently bring out the significance of the new results for the philosophy of science.

But the layman is also interested in the other side of the question, in the bearing which this revolution of human thought has on metaphysics. He wishes to know to what extent it affects his cherished beliefs and convictions, and, justly or unjustly, he accuses the scientist of refusing to gratify this wish. For instance, we read in the "Experiment in Autobiography" by H. G. Wells: "It is curious to find that to-day professors of physics . . . are still failing to be . . . lucid on such old-world problems as predestination and free will."

Of course, the wording of this remark is unfair to the "professors of physics," as it seems to imply that they are shirking a duty. In reality, however, predestination and free will are problems rather of divinity than of physics. No fair-minded person can blame the physicists for minding their own business and being reluctant to write or talk about theology. But it is true, on the other hand, that even some of the authoritative popular presentations written by scientists of high standing just stop short of the crucial question: "Do the new results of physics have any bearing on the problem of free will, and if so, what is it?" Probably the reason for this omission lies in the fact that these authors, while well versed in the scientific side of the problem, did not sufficiently analyze its theological aspects. At any event, there is an unquestionable demand for such an investigation. Therefore, I have selected as the topic of my article the question put forward by H. G. Wells, and I am prepared to go deeper into theology than is customary in scientific talks. In this sense should be understood the title, "Physics and Metaphysics."

To be sure, it is not the place of a scientist to take sides in a religious controversy. But when it comes to the question, to what extent a specific position of theology is in agreement or in conflict with the accepted theories of science, then the scientist has the right, and even the duty, to speak up.

I shall begin with a brief exposition of the concept of predestination. Predestination is the doctrine that *all happenings in the universe were foreseen by God from eternity and take place, only, through His will.* None of the major religions of mankind remained unaffected by this doctrine. In ancient times, the Greeks had the notion of the "Moira," the unescapable fate to which all men are subject. The Brahminic Hindoos called a similar concept "Karma" and, in a

somewhat milder form it was taken over by Buddhism. In the old testament this doctrine is hardly mentioned, but it is set forth with full force in the apocrypha, especially, in the apocalypses of Esdra and of Baruch.

Predestination became a major difficulty of theology when the Christian church fathers, especially St. Augustine of Hippo, combined the principle of predestination with the Hebrew idea of a personal God who is interested in his creatures and is guiding their steps like a kind father, rewarding the worthy and punishing or forgiving sinners. If all the actions of his creatures were foreordained by God, men have no choice in committing them or leaving them undone: They have no freedom of will. There arises the situation which formed the perennial theme of Greek tragedy: Man is but a helpless pawn pushed about by an irrevocable fate and, yet, a cruel Nemesis holds him responsible for actions which were not of his free choice. The Greeks saw in this a great calamity, an eternal curse hanging over mankind, but not an unjustice, because they did not possess the biblical notion of a kind and gracious Deity. But our modern moral sense revolts at the idea that God should have condemned a part of humanity to eternal suffering (as the technical expression is, "*reprobated*" them) and "elected" another part to everlasting bliss. St. Augustine himself argued that, since man is inherently bad and wicked, there is no unjustice in leaving him to his deserts. As Hamlet says: "Use every man after his deserts, and who should escape whipping?" It may be answered, however, that if mankind is wicked, it is so through the will of God by his decree. Rebecca West, in a little book she wrote about St. Augustine, makes a clever remark about this point of his teachings. He was the first born of his parents and the favorite of his mother, Ste. Monica. He never outgrew the psychology of the favorite child, jealous of his brothers and sisters, and he transferred the spirit of the nursery into his ethical system. Provided he belonged to the elected, he was perfectly willing to have the others damned.

In brief, the difficulty lies in the incompatibility of the two attributes of God: His omniscience and omnipotence, on the one hand, and His all-kindness, on the other. If God is all-wise, He must have foreseen everything, and man can have no free will. But, in order to exercise His justice and grace by rewarding, forgiving or punishing, He must deal with creatures who are free and responsible. It is no exaggeration to say that the larger part of Christian theology was devoted to the problem of predestination. In St. Augustine's own life-time, took place his famous controversy with the British theologian, Pelagius, who held the opposite view that man's will is free and only strengthened and encouraged, in its moral purpose, by divine grace. In the scholastic period, St. Thomas Aquinas was a follower of St. Augustine, and Duns Scotus a semi-Pelagianist. Later the Dominicans represented the Augustinian school of thought, and the Jesuits the semi-Pelagian, which seemed to be the more widely accepted. However, in the seventeenth century the decaying Augustinian views were revived by the Jansenists.

Among the Protestants both Luther and Calvin accepted the doctrine of predestination, while the Dutchman Arminius was the main advocate of "Synergism" (as the Pelagian view of freedom of will combined with grace was called by the Protestants). Even to-day the teaching of predestination is a part of the creed of many Christian denominations, but somehow it has lost its power. The clearer minds among the churchmen of our time admit that *the problem of reconciling the fore-knowledge of God with the free will of Man is insoluble, but they maintain that it need not be solved.* We shall see that there is much wisdom in

it which is not only the evasive wisdom of the ostrich.

The philosophical equivalent of predestination is *determinism* which was particularly emphasized by Spinoza. In Spinoza's pantheism God and nature were equivalent, the nature being one of the two aspects of the divine substance, the mind, the other. The wisdom of God had therefore to be translated into the lawfulness and consistency of the happenings of the physical world which constitute determinism.

So much about theology and metaphysics. Let us now return to science. We may ask: "Where from did religion derive the doctrine of predestination?" We have just recognized that predestination is equivalent with determinism, and this, in turn, is only one of the formulations of the *principle of causality*, playing such a big rôle both in science and in philosophy. Much has been written about causality, but most of the discussions are concerned with its psychological and metaphysical aspects which are entirely beside our point. We shall be interested here only in the logical aspect related to the fundamental assumption of Aristotelian logic that it is possible to deduce from certain given propositions (premises) another proposition (conclusion) in a unique way. Meaning by this that, when the premises are, in two cases, the same, the conclusion is also the same. Since logic is the instrument for the interpretation of our scientific experience, the principle of causality has been taken over by science. The material of science lies in its facts or observations; they take the place of the premises and conclusions in the scientific applications of logic. As understood in science, the law of causality can, therefore, be stated in these words: a given set of earlier observations (causes) is always followed by a uniquely determined set of later observations (effects). This principle turned out to be in agreement with the scientific facts, *within the limits of observational errors*. Of course, the effects of any set of conditions will be, in their turn, the causes of new phenomena at a still later time, and so on. In this way we arrive at the notion of the causally connected chain of observations and at the deterministic world picture which received its sharpest formulation by Laplace in the following paragraph from his theory of probabilities:

> An intellect to which were known all the forces acting in nature, at a given time, as well as the positions of all things composing the universe, provided it were comprehensive enough to subject all these data to analysis, could embrace in one and the same formula the movements of the largest celestial bodies and of the tiniest atoms. Nothing would be uncertain to it, future and past would be equally open to its eyes.

There is a remarkable similarity between the all-embracing intellect with its world formula, imagined by Laplace, and the omniscient God. Laplace says: "Nothing would be uncertain to it, future and past would be equally open to its eyes." While the psalmist puts it more poetically but less strongly, "A thousand years are in thy sight like yesterday," the basic idea is in both cases the same. We begin to suspect that the religionists created their God in the image of a perfect scientist. Of course, we do not imply that they were influenced either by Aristotle or any other representative of science. What we mean is that the acceptance of the concepts in question was an act of scientific thinking on the part of the founders of religion themselves. They got hold of a principle of science, the law of causality, and incorporated it into their system as an article of faith, the doctrine of predestination. This was a very unwise thing to do: An article of faith must be absolute and beyond human inquiry, while a principle of science is never final but always subject to refinement and revision. Of course, neither the metaphysicians nor the scientists realized that the principle of causality was not an absolute truth.

Both declared it a "necessity of thinking," but it happened time and again in the history of science that what was considered a *necessity of thought* turned out to be only a deeply ingrained *habit of thought*. The experience seemed to indicate that the same causes always produce the same effects and man came to believe that it must be so and never could be otherwise. However, when the new discoveries of physics proved to the scientists that this view is mistaken, they abandoned determinism without much trouble. The difficulty with any positive statement in science is that it can not be proven absolutely but only *within the errors of observation*. It is clear that accuracy is very essential for the Laplacean hypothetical intellect. The slightest error in the determination of the direction and velocity of a moving body will lead to a deviation from the calculated position which will increase with time. After the lapse of a sufficiently long time the body will be found very far indeed from where it is expected, be the lack of precision ever so slight. In other words, absolutely accurate data must be available to the intellect or its omniscience will cease after a shorter or longer time and the whole world picture of Laplace will collapse. Is the required absolute accuracy possible?

In Laplace's own time the experimentation was very crude and the observational errors rather large. It was surmised, however, that this state of affairs was wholly due to the limitations of the observer and not to any peculiarities of the laws of nature themselves. The point of view of Laplace implies the belief that in the hands of an ideal experimenter the accuracy could be increased without limit. This is the place where the modern ideas differ from the old ones. It is true that the experimental precision was, and still is, increasing at an ever accelerated rate so that the modern instruments and the modern technique are marvels of accuracy as compared to those which were familiar to Laplace. But at the same rate as the methods of science were refined they were applied to the measurement of smaller and smaller quantities, so that the ratios of the errors to the measured amounts have not greatly decreased. Science has now the proof of the corpuscular structure of the world: the ultimate units of matter are called electrons, protons, neutrons, those of light are known as photons. The observation of such systems, without disturbing them in their natural course, would require means which are delicate in comparison with them. However, such means do not exist: the only way of learning something about the motion of an electron or photon is to observe its action on other electrons and photons. But in this interaction the original state of motion of the particle is changed. This is the inner reason for a very fundamental law of physics discovered a few years ago, the so-called *principle of indetermination*, which states that the position and the velocity of a particle can not be accurately determined at the same time (and which also states the minimum limits of the experimental error).

How does the principle of indetermination affect the law of causality? We may say that it lies beyond causality: the principle of logic remains true that from given premises there always follows a unique conclusion, but it does not apply when there are no premises or not sufficiently accurate premises. Science can no longer invoke causality without reservations: when there is no precise knowledge of the causes, the effect can not be predicted with absolute certainty. It must be distinctly understood that this lack of precise knowledge is inherent in the nature of the laws of the physical universe. It is well to mention here an objection, so natural that it is raised by novices almost regularly: "Granted that the knowledge possessed by the scien-

tist leaves the future motions of a particle partially indeterminate. How can they be sure that this knowledge is complete, that there do not exist other measurable parameters which are still hidden to them, but would be apparent to the more powerful intellect envisioned by Laplace? This additional information could make the problem determinate and causal in the sense of the classical theory." In the early stages of the modern development the question of the "hidden parameters" was amply discussed. Of course, it would be dogmatic to assert that their existence is entirely out of the question. However, it is safe to say that most scientists consider it as very unlikely and that such parameters could not be introduced without abandoning or radically changing the whole mathematical structure of the now existing theory.

After all, for the purpose of the present analysis it is sufficient to have in mind that the causal point of view is not the only possible one. Modern science has developed another (the statistical) standpoint which is just as logical and self-consistent and is in far better agreement with the experimental facts, as they are at present known. If we shift our ground to the new point of vantage the question as to the accurate simultaneous determination of position and velocity simply loses its meaning. The hypothetical intellect of Laplace, be it ever so grandiose, is subject to the same limitations as every other observer and its world formula becomes useless. As it works out, the intrinsic error of observation is comparatively unimportant for large bodies and significant only for small particles. The intellect could, therefore, give a valid prediction of the motion of planets and other celestial bodies for a long period of time, but, in the case of atoms and electrons, its calculations would fail immediately.

The difference between the old (deterministic) and the new point of view, in relation to predicting the future, is best illustrated by a simile. Let us consider, *on one hand,* the surface of the moon: At present, we can not see its minute details. However, we are sure that we could build telescopes sufficiently powerful to discern them. It is only a question of money and technology. Let us take, *on the other hand,* the crude reproduction of a photograph in a newsprint. Here, too, we can not see the details because they are blurred. But unlike those of the moon, no amount of magnification, no lenses or microscopes can ever make them visible. In a similar way, the future is not accurately predictable because the structure of space and time is inherently blurred and fuzzy. Even the most omniscient and omnipotent being can not see things that are not there, so that this is no reflection upon the wisdom and might of God. Our comparison is also adequate in bringing out the fact that the principles of science permit the prediction of the rough general features of future events and, only, deny the possibility of foreseeing their finer details.

It is clear from this description that the new discoveries of physics sound the death knell to the concepts of determinism and predestination. It has often been assumed, tacitly or explicitly, that this remark also disposes of the even more important question of the free will; namely, in favor of its existence. This is, however, an entirely erroneous assumption. The bearing of the changed point of view in science on the freedom of will is an independent problem requiring a separate investigation. *It is our contention that the traditional linkage between determinism and free will is converted into its opposite on the newly shifted ground of science.*

There always have been two schools of thought among the metaphysicians. Those of the first school (the "Vitalists" and "Neo-Vitalists") hold that the laws derived by science for dead nature have

only a limited application to the operation of the psyche and to the actions of man. It is obvious that discoveries in the field of physics will not affect their views on the freedom of will which, according to them, belongs to a different sphere. To the other school belong the "Mechanists," who maintain that human behavior is governed by the same laws as physical nature. What conclusion must the Mechanists draw from the principle of indetermination? From the old point of view, the negation of determinism automatically admitted the free will as a possibility. But, as we shall see, this connection of the two principles is no longer true. Freedom of will implies man's ability of choosing and directing events. But the new principles of science do not grant him this ability any more than the old ones. Owing to the inherent inaccuracy of physical description, the same causes may produce, at different times, different events. But these events are unpredictable and subject only to chance. This implies, of course, that neither man nor God can direct these events, because, if he could guide them, he also would be able to foresee them. If under the reign of the principle of causality man was a helpless tool of predestination, modern science makes him, in part, an equally helpless plaything of blind chance. It seems that this simple fact has not been generally recognized. The reason for this was pointed out in our introduction. Scientists, as a class, are not greatly interested in the bearing of their results on philosophy. Even those of them who wrote on the subject for popular consumption devoted most of their attention to the scientific side and touched upon the metaphysical implications only in a desultory manner without clearly realizing that determinism and free will involve, in this connection, two different problems. However, once the distinction is made, the argument becomes quite cogent and conclusive.

We conclude with a brief summary of our main points: (1) The views of modern physical science are incompatible with the doctrines of predestination and determinism which are no longer tenable. This statement should not be construed as an attack upon religion and metaphysics; in fact, it should be a boon to them. It will be well to repeat here that the metaphysicians were those who invaded the field of science by postulating as a truth the religious equivalent of the law of causality. In doing this they quite unnecessarily created for themselves difficulties which they could not resolve. Science is now showing them the way out of the dilemma. (2) The discoveries of physics referred to do not change, in any way, the status of the problem of the free will. Followers of the mechanistic point of view (who believe that the laws of nature and of the human mind operate in the same way) must, therefore, continue to deny freedom of will. Members of the vitalistic school, on the other hand, who claim that human behavior is not subject to the same laws as the physical world, are at liberty to accept the will as free. Their point of view becomes now a little more self-consistent because it does no longer get in conflict with predestination.

I wish, however, to add a word of warning: Although, at present, science can not answer the question whether the laws of the human psyche and of dead matter are the same or not, it will be able to answer it in the course of time. It is definitely a question of science and not of metaphysics. Mechanists and vitalists may hope that the future will vindicate their particular views, but they may not claim for their hopes the dignity of metaphysical postulates.

A TOUR THROUGH PROBABILITY DOMAINS

By E. C. MOLINA
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I

On a tour, whether by train or boat, it is good form to be sociable and join your fellow passengers if they propose a game of bridge.

But playing bridge is more than a pastime. The implications of card shuffling have taxed the mathematical powers of such men as Poincaré, Markoff, Hadamard, Hostinsky, Frechet. They posed and discussed this problem: Given an initial arrangement of the cards, what is the probability that after a specified number of repetitions of a particular way of shuffling them, the cards will be found arranged in a preassigned order?

Poincaré, Markoff, *et al.*, proved that if the number of shufflings or operations on the cards (to use their more technical language) approaches infinity, then the probability asked is independent of the initial arrangement of the cards or of the shuffling method used. They proved several other theorems, all of which are now to be found in the literature under the caption "probabilities in chain."

Let us consider a method of shuffling which would be frowned upon at a bridge tournament, but which is pregnant with meaning for the scientifically minded.

Put half of the cards in a box labeled A, and the other half in a box labeled B. Shake the boxes vigorously and draw a card simultaneously from each box. Next, place in A the card drawn from B and in B the one drawn from A. Call this sequence of drawings and interchange of locus an operation and repeat the operation a large number of times. Bearing in mind that half of the cards are red and the other half black, one will be prepared to consider a whole class of problems in molecular physics. But before taking up the physical problems, permit me to restate the card problem in the form that Laplace gives it in the "Théorie Analytique des Probabilités":

> Consider two urns A and B each containing n balls and suppose that of the total number of balls, $2n$, as many are white as black. Conceive that we draw simultaneously a ball from each of the urns, and that then we place in each urn the ball drawn from the other. Suppose that we repeat this operation any number, r, of times, each time shaking well the urns in order that the balls be thoroughly mixed; and let us find the probability that after r operations the number of white balls in urn A be x.

As in the case of the cards, after a large number of operations, the probability in favor of any specified division of the white and black balls between the two urns is independent of the initial arrangement. Therefore, with a finite number of balls there is a finite probability of reproducing the initial distribution. This fact has great significance, particularly if initially all the white balls were in one of the urns and all the black balls in the other urn.

II

Now, if it please the reader, I submit two exhibits connecting the card shuffling or Laplacian ball problem with modern physics.

Exhibit A

Lotka, in his "Elements of Physical Biology," Chapter III, under the heading, "The Statistical Meaning of Irreversibility," says:

> Let the vessel A contain 1 gram of nitrogen gas, and let B contain 1 gram of oxygen gas, the communication between A and B being closed. It is a matter of common knowledge that if the stopcock is now opened, the gas from

A will flow over into vessel B and *vice versa*, and in a short time an equilibrium is reached in which each vessel contains 0.5 gram of each gas. Now, in point of fact, the molecules of gas behave (approximately) like a number of elastic spheres, their equations of motion contain no dissipative term, but are of type (3) (Chapter II). We should, therefore, expect that after a certain lapse of time, the initial condition should return, and that all the nitrogen should once more be contained in the vessel A, all the oxygen in B.

Lotka continues the discussion of this phenomenon with an appeal to probability theory and makes use of the Laplacian ball problem as an illustration.

The physico-statistical ideas quoted from Lotka were epitomized by Bertrand Russell in a popular article entitled "Heads or Tails" (*Atlantic Monthly*, August, 1930). He wrote:

If you put a kettle on a nice hot fire, will the water freeze? "Certainly not," says common sense, indignantly. "Probably not," says physics, hesitantly. According to physics, if every member of the human race put a kettle on the fire every day for the next million million years (during which, according to Jeans, the world is to remain habitable), it is not unlikely that sooner or later the water in one of these kettles would freeze instead of boil(ing).

Of course, by "physics" Russell means modern physics from the point of view of the kinetic theory of matter, or probability.

Exhibit B

In his paper entitled "Application du Calcul des Probabilités á la Théorie du mouvement Brownien,"[1] Hostinsky introduces his section on linear Brownian movements with a short discussion of the Laplacian ball problem.

For the benefit of those unfamiliar with Brownian movements I quote from A. L. Kimball, "College Physics," 2nd ed., 1917.

The English botanist Brown in 1827 on observing with the microscope very fine particles held in suspense in a mass of water, discovered they were in constant irregular motion, and the smaller the particle the more lively was the motion observed. It is a spontaneous motion that never ceases, and is believed to be caused by the incessant motion of the molecules of the liquid.

The French physicist Perrin has made a careful study of this phenomenon using an emulsion in water of exceedingly fine grains of mastic. He finds by exact measurements of the distribution of the grains and the amount of their motions that they distribute themselves just as should be expected from the kinetic theory, and even deduces by inference from his measurements the number of molecules in a cubic centimeter of gas under standard conditions, finding 30.5×10^{18}, in good agreement with determinations by other methods.

III

To solve his ball problem, Laplace first set up an equivalent finite difference equation and then, as an approximation, reduced it to a partial differential equation. I would invite the reader's attention to this differential equation from two points of view, one physical, the other mathematical: (a) The equation has reappeared in modern physics in connection with the theory of Brownian movements. In this connection I will refer you again to the article by Hostinsky in the *Annales* of the Poincaré Institute. (b) The solution of the equation led Laplace to the development of polynomials and an expansion in these polynomials which, to-day, are called Hermitian and Gram-Charlier, respectively.

But what are Hermite polynomials and Gram-Charlier series, more particularly, the Gram-Charlier A series? An analogy will help us here.

A complex problem in dynamics frequently reduces, as we all know, to a combination of several simple harmonic motions. Moreover, a simple harmonic motion is represented mathematically by a sine or cosine function. Therefore, it is not surprising when the analytical solution of the complex dynamical problem comes out in the form of a sine and cosine series. But consider the domain of, let us say, biology. Here the elements of a complex problem are not sim-

[1] *Annales de l'institut Henri Poincaré*, Vol. III, pp. 47 and 50.

ple harmonic motions; they are simple chance phenomena, simulated by the tossing of pennies or drawing of balls from a bag. In this case, we anticipate that the analytical solution of a complex biological problem would be given by an expansion whose terms represent simple chance events. Such is the character of the Gram-Charlier A expansion, wherein Hermite polynomials of successive orders take the place of the sines and cosines of a Fourier series.

At times even a dynamical problem comes within the scope of Gram-Charlier series. This comes about when the entry of the forces acting or the intensities of their effects are conditioned by circumstances of a random character. As an example one may take the problem of perturbations in the statistical theory of celestial mechanics. Those interested in astronomy could quite well enjoy a pleasant evening discussing Gram-Charlier series with the biologists. As an opener for an exchange of ideas, one might consider the following statement made by Charlier in the chapter dealing with expansions, in the fascicule on astronomy of Borel's "Traite du Calcul des Probabilités et de ses Applicationes":

> Each event, each attribute, each object, each fact, may be regarded as the outcome of the superposition of a very large, or infinite, number of very small influences emanating from sources of perturbations capable of exercising any action whatsoever on the object in question.

IV

Laplace did not stop with two urns. He said:

> We may extend all this analysis to the case of any number whatever of urns; we will limit ourselves here to finding the mean value of the number of white balls each urn contains after r operations.

This more general problem suggests questions regarding the number of so-called *complexions* corresponding to a given statistical state, thermodynamic probability and its relation to entropy.

Consider the above diagram from Page's "Introduction to Theoretical Physics."

The seven squares or cells (boxes) represent elements of extension-in-phase. The ten dots with their identification numbers represent, collectively, one of the many complexions corresponding to the particular statistical state of 1 particle in cell No. 1, 2 in cell No. 2, 1 in cell No. 5, 4 in cell No. 6 and 2 in cell No. 7. For this particular state the total number of complexions is

$$\binom{10}{1}\binom{9}{2}\binom{7}{1}\binom{6}{4}\binom{2}{2} = 10!\,/\,(1!\ 2!\ 0!\ 0!\ 4!\ 2!)$$

The most probable state is the one to which the greatest number of complexions correspond.

Now, with due apologies for being so abrupt and for a purpose which will soon be apparent, I will jump, for a more general statement of the complexion problem, to page 283 of an "Introduction to Statistical Mechanics for Students of Physics and Physical Chemistry," by James Rice:

> Suppose we have present a set of Planck vibrators which each contain a multiple of a unit of energy e. Let there be n vibrators and an amount of energy E available where E/e is an integer. Let us consider a complexion in which there are n_0 vibrators with no energy, n_1 with e, n_2 with $2e$, etc. There are as usual
>
> $$n!\,/\,(n_0!\ n_1!\ n_2!\ \ldots)$$
>
> complexions in a corresponding statistical state, and we have to satisfy the conditions
>
> $$\begin{aligned} n_0 + n_1 + n_2 + n_3 + \ldots &= n \\ n_1 + 2n_2 + 3n_3 + \ldots &= E/e \end{aligned} \qquad \text{(IV. 1)}$$

Let C be the total number of complexions compatible with these conditions. C will be given by

$$C = \Sigma\, n! \,/\, (n_0!\; n_1!\; n_2!\; \ldots)$$

where the summation is over all possible values of the n *which satisfy.* (IV. 1).

It is not my intention to follow up this complexion problem. My main purpose in introducing it is that Rice evaluates C by the method of generating functions, a method which appeals to me like apple pie to a small boy.

V

The concept of a generating function suggests itself immediately to one familiar with the history of art.

When the Greeks wanted a Parthenon, they called upon a Pheidias. When the Medici wanted a magnificent tomb in San Lorenzo, they called upon a Michelangelo. But, during the dark ages, when a Pope wanted a beautifully carved portal, for example, there was no Pheidias or Michelangelo to call for. So, instead, scouts were sent out to buy up some ancient building containing a portal of the desired design. Then, the building having been acquired, a wrecking crew was sent to extract the portal.

This method of accomplishing results has turned out to be very fruitful in the mathematical theory of probability, and elsewhere. When a mathematician can not carve a desired function, $f(x)$, he looks around for a generating function, $F(x)$, containing $f(x)$. Then, if necessary, applying some ingenious wrecking tools devised especially for the purpose, he extracts $f(x)$ from $F(x)$.

In the generating function or frequency array (see "Frequency Arrays," Soper, Cambridge University Press, 1922)

$$F(A, B, C, \ldots) = \Sigma\Sigma\Sigma \ldots (p_{a,b,c} \ldots)\, A^a B^b C^c \ldots$$

the coefficient $(p_{a,b,c}, \ldots)$ is for a certain population, the proportion or frequency of individuals each owning, say, a automobiles, b books, c cows, etc. Likewise, with reference to continuous variates, in the generating function, or frequency array,

$$F(A, B, C, \ldots) = \int\int\int \ldots f(a, b, c, \ldots)\, A^a B^b C^c \ldots da\, db\, dc \ldots,$$

$f(a, b, c, \ldots)$ gives the proportion or frequency of individuals of, say, age a, blood pressure b, chest expansion c, etc.

The capital letters symbolize characters or attributes in which we are interested, and the frequency array pictures the entire population as divided into categories in accordance with the extent to which an individual possesses each of the characters or attributes.

The method of generating functions constitutes a highway with branches running in all directions. Traveling along it carries one through the entire domain of error theory. The branch built by Soper terminates in a whole family of random flight problems. In Soper's treatment of these problems will be found not only evidence of the power of generating functions, but also a masterly exhibition of how powerful tools should be handled. It will be recalled that random flight problems are of the type: If one, with the aid of an aeroplane, makes a flight of n successive steps, each step of length r in a random direction with reference to the preceding step, what is the probability that at the end of an assigned time interval one is at an assigned distance from his starting point?

The number of physical problems which may be classed together under the heading of random are legion. For example, many, if not most, of those concerned with Brownian movements; the problem of "fading" in radio transmission; the problem which in Volume I of his "Theory of Sound," Lord Rayleigh states as follows:

We have seen that the resultant of two isoperiodic vibrations of equal amplitude is wholly

dependent upon their phase relation, and it is of interest to inquire what we are to expect from the composition of a large number (n) of equal vibrations of amplitude unity, of the same period, and of phases accidentally determined.

Rayleigh and Karl Pearson may be mentioned as among the pioneers in the treatment of random flight problems.

VI

So far I have submitted for consideration strictly scientific implications of card shuffling. I now invite attention to a shuffling problem which involves, as we shall see, a very delicate ethical question.

In the game of poker each player is dealt five cards. That five-card hand which consists of the ace, king, queen, jack and ten of a suit possesses the highest playing value; it is called a "royal flush." If the cards are dealt at random, the probability that the dealer's hand will constitute a royal flush is only 1 in 649,739 or, approximately, 1 in 650,000. On the other hand, by cheating, the dealer can raise this extremely small probability up to, let us say, 1 in 100.

Now suppose a stranger, who proposed a poker game, dealt the cards and that, when the hands had been played, it developed that he had dealt himself a royal flush: What is the probability that he cheated?

Shall we say that the odds are 650,000 to 100 against his integrity? Such an inference is legitimate only if, before the hands were played, we were in a fifty-fifty state of mind regarding the stranger's ethical status. Certainly no one would bet 650,000 to 100 against him if the occurrence under consideration had taken place within the sacred precincts of a London club, for example. But we are on a train or ship, and signs, hung in conspicuous places, give warning as to the likelihood of our encountering card sharps. Therefore the odds against the good faith of the stranger, who has dealt himself a royal flush, are even greater than those already cited.

The moral to be drawn from the ethical problem we have just discussed is as follows: When an event has happened as the result of the coming into play of one or the other of two causes, A and B, the probability in favor of cause A, for example, as being the cause which actually resulted in the observed event, is proportional to two distinctly different factors; one factor gives the probability in favor of said cause A before the observed event occurred; the second factor is proportional to the probability that, if cause A is in action, then the observed event would occur. The first factor is called the *a priori* existence probability in favor of the cause. Two corresponding factors pertain to the other cause B. The generalization of our little sermon to the case where more than two causes must be considered involves no difficulty other than the use of a greater number of words.

CHANGEABLE COLORATION

ITS MECHANISM AND BIOLOGICAL VALUE WITH SPECIAL REFERENCE TO FISHES

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THE ability to undergo rapid changes of color and shade in response to external stimuli is confined to a very few groups of animals, though these groups belong to several different major divisions of the animal kingdom. Since the mechanisms involved in these changes present essential differences in some of the groups which possess them, we may be reasonably sure that this capacity has appeared several times in the course of animal evolution. The chief groups which display it are the cephalopod molluscs, crustacea, fishes, amphibia and reptiles.

The effector elements which are immediately responsible for these color changes are cells known as chromatophores. These may operate singly or in clusters of a few cells. Speaking particularly of the fishes, we may say that the chromatophores are much branched cells of relatively great size. In form, they may well be compared to a basket star-fish, having a small central disk and radiating branches which subdivide repeatedly. There are various kinds of these chromatophores, but the most important differences relate to the kind of pigment which they carry. Thus we have the most numerous class, the melanophores, which contain the black pigment melanin; the xanthophores and eythrophores—yellow and red, respectively—which contain pigments of the carotenoid type; and the white guanophores or iridocytes which contain crystals of guanin.

In all these the response to a stimulus consists in the shifting of the pigment within the cell. The older view that the chromatophores themselves expand and contract in ameboid fashion has been virtually abandoned, though this misleading terminology unfortunately persists. The darkening of a fish results from the centrifugal movement of the melanin granules, which thus come to fill the branches of each cell and greatly increase the total black area of the skin. In paling, the pigment granules move in a centripetal direction, concentrating in a small mass in the center of each cell. Thus, the same fish, under appropriate stimuli, may change in shade from dead black to pale brown and back again within a few minutes' time. Similar processes occur in the other types of chromatophores.

In fishes, there seems to be an immediate connection between the chromatophores and the terminations of peripheral nerves belonging to the autonomic system. This fact has been substantiated both by histological and by physiological studies.

That the xanthophores are controlled by different nerves from the melanophores is evident from the fact that these two types of chromatophore react independently of one another and often in opposite directions. A fish may become pale and colorless or pale and yellow; dark and colorless (*i.e.*, black or gray) or dark and yellow (*i.e.*, brown). The behavior of the other types of chromatophores is less well known. Recent studies seem to indicate that the centrifugal and centripetal movements of pigment, *i.e.*, dispersion and aggregation, are also controlled by different nerve fibers.

The direct nervous control of chromatophores has likewise been demonstrated for reptiles, though in this group there seems to be a supplementary control through the secretion of the adrenal medulla. In the amphibia, on the other hand, no such direct nervous control appears to exist. Quite the contrary, it now seems probable that the reactions of the chromatophores in the latter group are mediated entirely through endocrine secretions from the hypophysis, carried in the blood. These animals nevertheless react to optic stimuli, as fishes do, though they are more largely influenced than the latter by various other stimuli.

The recent work of Parker and his students seems to show, moreover, that even in the fishes there is a hormonal (or "humeral") control of the chromatophores, supplementary to the nervous control. If the nerve supply of a small area of the integument is severed without disturbing the blood supply, and the fish is then placed upon a white background, the entire body soon becomes pale, with the exception of the denervated area. If, however, the animal remains for a considerable number of hours upon the white background, the denervated area likewise gradually becomes pale. This, along with certain other experiments, would seem to show that some substance diffusing from one cell to another may bring about the same effect upon the chromatophores as stimulation through the nerves. Indeed, it is quite possible that the immediate action of the pigmento-motor nerves themselves is to stimulate the formation of substances capable of causing the concentration or dispersion of the pigment in the chromatophores.

The chromatophores are known to respond in a definite way to various drugs. Dilute solutions of sodium chloride, for example, bring about the so-called "expanded" condition of the melanophores, or more correctly the dispersion of the melanin granules within these cells, while potassium chloride produces the reverse effect. Here, it would seem to be the sodium and potassium ions which are effective. Many anesthetics, ether and urethane, for example, call forth the dispersion of the pigment, while adrenalin causes an extreme condition of concentration. It seems probable that the hormone of the adrenal medulla may normally play a rôle in the color changes of some reptiles.

Whatever the physico-chemical mechanism, the phenomena of pigment migration, as seen in the chromatophores of the scales of a fish, is a fascinating object of study, and could readily be utilized for classroom demonstration. I do not know to what extent this has been done.

As already stated, control of the chromatophores in all animals is effected either directly or indirectly through the nervous system. Color changes may occur in response to a variety of stimuli, photic, thermal, chemical or mechanical. In fishes, optic stimuli are responsible for the most conspicuous and biologically important changes. Here we must distinguish changes of color, in the narrower sense, from changes in shade, the latter denoting changes in the direction of greater pallor or darkness, without any necessary alteration of color proper. A fish placed upon a gray background, for example, assumes a quite different appearance from the one placed upon a brown or yellow background, which is equally pale or dark. Any one who has conducted experiments of this sort with any care knows that the wave-lengths of the light reflected from the background constitute an important element in the situation. While this conclusion has been challenged by some writers on more or less theoretical grounds, it has been sustained repeatedly by carefully planned experiments. That fishes have a real though perhaps restricted color vision can no longer be reasonably doubted.

Many of these chromatic changes of

fishes are remarkably complex, consisting not only of independent responses by the different classes of chromatophores, but of independent changes in different areas of the integument. Thus, in flat-fishes, certain areas may become very pale, others at the same time very dark, giving to the animal a mottled appearance. Moreover, the relative extent of the light and dark areas, in such cases, is closely dependent upon their relative extent in the background at the time. Once more, the resulting mottling is likely to be coarse or fine, depending upon the texture of the background.

I have spoken here of the background. Those unfamiliar with the color changes of fishes sometimes assume that the effective agent in determining the shade assumed by the animals is the total quantity of light to which they are exposed. Thus, fishes might be supposed to become black on a black background, by reason of the low degree of illumination, and pale upon a white background for the opposite reason. That this is far from being a true account of the situation we might suspect from the fact that, when kept in complete darkness, fishes become pale rather than dark. What the fish responds to, for the most part, is neither the total illumination from all sources nor the intensity of the incident light. The effective stimulus is the light reflected from surfaces beneath and around the animal. And even here it is not the absolute intensity of this reflected light which counts. It is rather the albedo of the reflecting surfaces. By albedo we mean the actual light-reflecting capacity of an object or substance, without reference to the degree to which it is illuminated. Thus, a gray object has a lower albedo than a white one, even though the former may be so placed as to reflect vastly more light than the latter. Simple photometric measurements suffice to show that even a dull black surface, placed in direct sunlight, may reflect more light (more *white* light, to be precise) than a white surface in the diffuse daylight of a laboratory room. And yet a fish becomes black, or nearly so, upon the former and very pale upon the latter.

The fish's response to a given albedo is to a large extent independent of absolute illumination. Here we have a striking parallel between the physiological responses of a fish and certain well-known facts of light perception in ourselves. I refer to the apparent constancy of a given color or shade under widely different conditions of illumination. It is the problem of "color-constancy," so-called, which has received considerable attention from experimental psychologists. Our perception of any one object in the visual field is not an isolated fact. It is influenced more or less by the entire visual field. In the same way, the fish reacts not merely to the light rays reaching its eyes from the background, but reacts, in some way, to the ratio between these rays and the incident light. Neither in man nor the fish is the making of the necessary "correction" for general illumination an act of judgment. It occurs entirely on the perceptual plane.

What, then, is this distinction between incident light and background? In the fish it seems probable that the animal's reaction is determined by the relations which obtain between the upper and lower portions of the visual field. For example, I long ago determined that a flounder made not the least response to a plate bearing a strongly contrasting pattern when this was suspended close over it. When, however, the position of the plate was reversed, so that the fish came to lie upon this same pattern, an appropriate rearrangement of its color markings occurred.

More recently, I have experimented with transparent celluloid caps or "false corneas," fitted over the eyes of the fish *Fundulus parvipinnis*. When the lower half of this "cornea" was painted black, thus obscuring the corresponding half of the visual field, the fish invariably became dark, usually as black as when placed upon a black background. On the other

hand, when the upper half of the visual field was obscured in this way, the fish did not become darker in consequence, but usually became paler than it would otherwise be upon a given background, unless, indeed, the background happened to be white. Apparently, darkening of the upper half of the visual field worked in the same direction as making the lower half paler.

Such experiments strongly suggest a dorso-ventral polarization of the retina, such that a given light stimulus will call forth a different response, depending upon the half of the retina which is stimulated. Or, possibly, this polarization occurs in the central nervous system. It is hardly necessary to add that such experiments rule out absolutely any interpretation of these adaptive color changes as direct and simple responses to photic stimuli, without regard to the complex anatomical and physiological mechanisms involved.

In the foregoing discussion, I have had in mind chiefly those rather prompt changes of color or of shade which result from the shifting of pigment within the chromatophores. I think that most of us formerly believed that the color-changes of fishes were altogether of this type. It was for long not realized that continued subjection to appropriate stimuli might result in large changes in the amount of pigment actually present in the tissues. Experiments of recent years have shown that in some fishes, at least, the black pigment melanin may be increased manyfold by a sojourn of a few weeks upon black, while it may be to a large extent eliminated by a sojourn on white. A more nearly quantitative series of experiments has recently been conducted by Mr. Peter Doudoroff and the writer, in which we sought to measure with approximate exactness both the conditions of illumination and the amount of melanin produced or lost.[1] These experiments, which were performed upon gobies, have revealed no such extreme differences in pigmentation as were encountered in some previous experiments with other fishes. They have shown, none the less, (1) that the amount of melanin produced (or retained) is strongly influenced by the albedo of the background, and (2) that it is influenced, though to a much smaller extent, by the absolute intensity of the illumination. While we do not wish to generalize at the present stage of this work, it may be allowable to point out that in our more brightly lighted cabinet, at least, the melanin content of the fishes tended to vary inversely as the logarithm of the albedo of the background. The relation of such a result to the "Weber-Fechner Law" is obvious.

As regards the yellow pigment, xanthophyll, the amount of this has been determined by Dr. D. L. Fox and myself for several species of fish.[2] The stock of xanthophyll in a fish seems to be derived entirely from its food and thus, ultimately, from the plant life of its habitat. Hence it must be maintained by appropriate feeding. In some fishes, at least, it is rather rapidly lost if lacking in the diet. It is interesting to note that this loss, in one species which we have studied, is considerably more rapid in specimens kept in white aquaria than in ones kept in black, gray or yellow aquaria. It was unexpected, however, that the amount of xanthophyll should fail to be closely correlated with the visible coloration of the fish. The distinctly yellow fishes from yellow aquaria yielded, to be sure, more xanthophyll than the nearly colorless specimens from white aquaria.[3] On the

[1] The report of these studies is in press.

[2] *Jour. Exper. Zool.*, 66: 263–301, 1933; *ibid.*, 71: 101–123, 1935; *Proc. Nat. Acad. Sci.*, 21: 330–340, 1935.

[3] That is, they did so with one interesting exception. Fishes which had been kept for a considerable period upon white, followed by a briefer sojourn upon yellow, were more highly colored than ones which had been kept for a considerable period upon yellow, followed by a briefer sojourn upon white. Nevertheless, the former yielded less xanthophyll than the latter.

other hand, the greatest quantity of all was obtained from the almost totally black fishes from black aquaria. Here, plainly, the xanthophyll was masked by the melanin.

In conclusion, we must face the question: What is the use of this remarkable mechanism for color change? The biochemist has to do only with the origin and composition of the pigments here concerned. The physiologist is interested primarily in the working of the mechanism. But the naturalist wishes also to know what rôle this plays in the life of the organism. That it plays some important rôle can hardly be doubted. Some substances which occur in the animal body may be dismissed as mere by-products of metabolism, and some structures may reasonably be regarded as functionless, at least at the present moment of evolution. But a complicated mechanism, consisting of many interrelated parts, can hardly be treated in any such summary fashion, particularly when it has been evolved independently in several different major divisions of the animal kingdom. And the fact that these changes of color are predominantly in the direction of rendering the animals inconspicuous can be ignored only by those who are not disposed to face the facts.

Unfortunately, there appear to be a number of such persons in existence and these have been vociferous in their assertions. Several biologists in different parts of the world have intermittently cudgeled the entire "protective coloration" hypothesis as being "anthropomorphic," "teleological" and unworthy of serious consideration by scientific men. It is not my intention here to enter into this controversy in any general way. Indeed, I am ready to admit that a certain fraction of the criticism is valid. I will merely refer, in conclusion, to some rather recent experiments of my own which show beyond cavil that the capacity of a fish to adjust its color scheme to its background may be of decisive value in determining the animal's survival.[4]

The experiments in question were conducted with a small species of fish (*Gambusia affinis*) as prey, and certain fish-eating birds and carnivorous fishes as predators. The fishes used as prey were first "conditioned" by being kept in black or white tanks for considerable periods, until their dark or pale liveries were fixed to the extent that individuals of different history could still be distinguished from one another after some hours' sojourn upon a common background. Throughout a considerable and varied series of experiments, the predators uniformly devoured a much larger proportion of the more conspicuous type of fish offered to them, even though both types were plainly visible, at least to the human eye.

To many, the inevitability of such results as these may seem quite obvious, and to such, indeed, the experiments themselves may appear altogether superfluous. But they could hardly be so regarded by those who continue to deny the effectiveness of all "so-called protective adaptations."

[4] *Proc. Nat. Acad. Sci.*, 20: 559–564, 1934; *ibid.*, 21: 345–353, 1935; *Amer. Nat.*, 69: 245–265, 1935.

THE CREATIVE YEARS: "BEST BOOKS"

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WHAT are the creative years? What are the chronological ages at which men (and women) are most likely to write literary masterpieces? Certain modern students of this subject have tended to overestimate the literary productivity of early youth; others have insisted upon the literary fecundity of old age and have perhaps exaggerated it. Overstatement is most likely to occur when an investigator merely lists a limited number of writers who have done excellent writing at some particular age level.[1] The technique of citing outstanding books that have been written by men of any given chronological age (and omitting the perhaps more frequent achievement at other age levels) is likely to yield an erroneous impression. The question is not whether there have been men of a given age (or age interval) who have produced excellent writing, but whether, in proportion to their numbers, men of some chronological age levels have produced more or less than men of other age levels.

The investigation that is reported herein reveals that superior books have been published by authors of almost every age level beyond early youth. Does it necessarily follow that there are no significant age differences with reference to literary creativity? Must it be inferred that there is a long period of maturity during which the publication of literary masterpieces is as likely to occur at one age level as at another? The present study provides tentative answers to the foregoing questions.

[1] *Cf.*, in this connection, W. A. N. Dorland. *The Welfare Magazine*, Vol. 18, Part 3, pp. 1307–1329; 1444–1466, 1927.

METHOD

In two previous articles[2,3] the fact has been stressed that when age differences in creativity are to be studied, it is necessary to take account of the varying numbers of individuals that are alive at successive age levels. For if more men are alive at the younger than at the older age levels, the younger age groups might publish more outstanding books merely because of their greater numerical strength. Accurate conclusions regarding the chronological ages at which individuals have most frequently produced literary masterpieces involve therefore: (1) Assembling a reasonably large sampling of very superior books, and (2) Determining the average number of these books that were published by each age group.

Several additional facts must be considered. It obviously is not possible to study the entire life work of authors who are still living and writing. There is no way of knowing what the living writers will accomplish during their later years. Moreover, books that are hailed with acclaim by one's contemporaries may not be regarded as great books by a critical posterity. The present study includes for the most part, therefore, data for deceased writers.[4] For these the record is complete, and future research will probably change it only slightly, if at all.

Which books should be included in a list of "best books"? How can we render

[2] Harvey C. Lehman, THE SCIENTIFIC MONTHLY, 43: 151–162, 1936.

[3] Joseph B. Heidler and Harvey C. Lehman, *The English Journal* (College Edition), 26: 294–304, 1937.

[4] There will be some exceptions to this rule. These exceptions will be noted when they occur.

a valid decision with reference to this question? Probably most readers would agree that no one individual is able to make a trustworthy decision as to which are the world's best books. At this point the writer wishes to express his indebtedness to an unintentional collaborator. In 1924, Mr. Asa Don Dickinson, librarian of the University of Pennsylvania, made a composite study of more than 50 "best book" lists. Dickinson made his study because he believed that his compilation would eliminate questionable titles. To quote from his own statement:

> No single authority is an absolutely safe guide. . . . By a careful collation of a large number of authoritative lists we can sift out the questionable titles, and be sure that no indispensable ones have been overlooked. It is by this laborious process that the One Thousand Best Books described in the following pages have been chosen.[5]

For studying the chronological ages at which best books have been most frequently published, a decided advantage is obtained by utilizing a composite list such as that of Dickinson. When they were making their original selections, the various compilers whose work was investigated by Dickinson were apparently not thinking of age differences in creativity. It is therefore probable that, collectively, the compilers exhibited no bias for or against any particular age group. This point is an important one for, when studying the relative creativity of persons of different chronological age levels, the investigator should divest himself of all bias. This impartial attitude is most likely to be maintained when the compiler is thinking not of age differences but solely of literary merit.

Literary Masterpieces

Fig. 1 presents the chronological ages at which 224 significant books were first published by 101 noted authors. Each of the 224 titles employed in the construction of Fig. 1 appears on 8 or more of the best book lists studied by Dickinson. These 224 books are obviously works of very superior merit. Because each of the 224 books appears on 8 or more of the best book lists, they will be referred to hereinafter as "Grade 8" books. Similarly, the expression "Grade 12," as used in this discussion, applies to books which appear on 12 or more of the best book lists studied by Dickinson. The foregoing system of notation will make for brevity of expression.

In studying Fig. 1 it should be borne in mind that this figure presents the *average* number of Grade 8 books per chronological age level. Adequate allowance is thus made for the relatively large number of authors alive at the younger age levels. For example, in obtaining the data set forth in Fig. 1, it was found that at the age interval 40 to 44 inclusive, the average number of Grade 8 books per author was .1004, whereas, at the age interval 65 to 69 inclusive, the average number of Grade 8 books had fallen to .0125. In Fig. 1 the curve is so drawn as to be only about one eighth as high at ages 65 to 69 as at ages 40 to 44, thereby indicating that average productivity was only about one

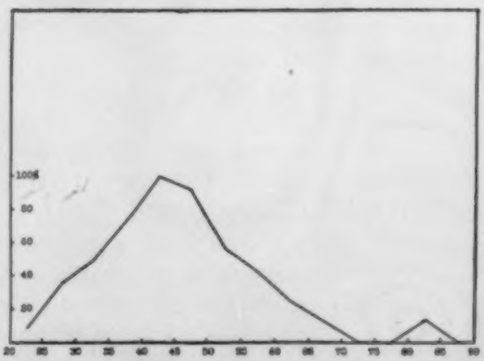

Fig. 1. Average number of best books by authors during each five-year interval of their lives. This graph is based on first publication of 224 significant books which were written by 101 noted writers.

[5] Asa Don Dickinson, "One Thousand Best Books," p. xii. Garden City: Doubleday, Page and Company, 1925. Pp. xvii + 416.

eighth as great at ages 65 to 69 as at ages 40 to 44.[6]

If, regardless of the number of authors that remained alive, the older writers had published books of Grade 8 quality at the same average rate as did the writers of ages 40 to 44 inclusive, the curve in Fig. 1 would remain as high at the older age levels as it is at the age interval 40 to 44 inclusive. Actually, the curve in Fig. 1 descends markedly after attaining its peak at the age interval 40 to 44.

Why does this marked descent in the curve of Fig. 1 occur? Is this decrement due to the phenomenon of old age? It is commonly supposed that the technique of producing literary masterpieces is one that is acquired slowly and painfully. One might logically have anticipated, therefore, that, having acquired this desirable and rather rare technique, the capable author would continue to employ it over a period of many years. This, of course, does occur in the case of some few authors. It does not occur, however, in the majority of instances.

In Fig. 1 a small polygon may be seen at the extreme right of the curve. This phenomenon is due solely to the fact that the second part of Goethe's "Faust" was published when Goethe was more than 80 years of age. Since, of the 101 authors whose works were employed in the construction of Fig. 1, only a very few were alive at age 80, Goethe's single publication at this advanced age interval yielded an average of .015 for writers of ages 80 to 84, inclusive. Study of the statistical distribution that is pictured in Fig. 1 reveals, however, that the publication of a work of such great merit by a writer who is more than 80 years of age is most unusual. Indeed, appropriate computation suggests that, if an author is destined to produce a book of such unusual merit as to be chosen by 8 or more compilers of best book lists, the chances are much less than one to a thousand that the author will first publish the book when he is beyond 80 years of age.[7]

Fig. 2 reveals the age intervals during which superior books of varying orders of merit were first published. In Fig. 2 the following characteristics are perhaps worthy of notice. (1) All four curves reach their peaks during the forties and three of the four curves attain their peaks prior to age 45. (2) The four curves all exhibit rapid descent prior to age 50, and (3) at ages 55 to 70 there seems to be a tendency for the curves

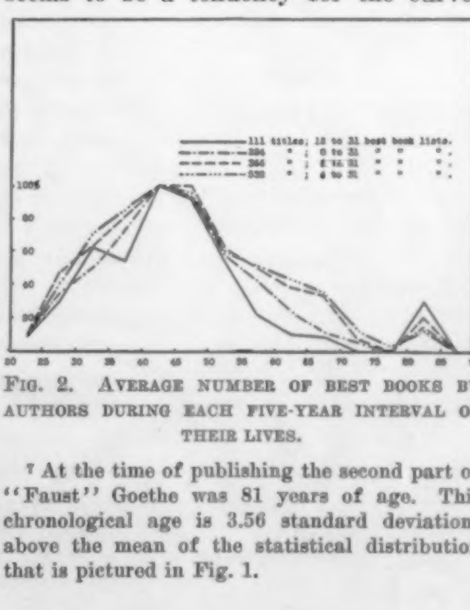

FIG. 2. AVERAGE NUMBER OF BEST BOOKS BY AUTHORS DURING EACH FIVE-YEAR INTERVAL OF THEIR LIVES.

[6] In constructing the graphs that accompany this article, the data were reduced to a percentage basis by the following procedure. The peak of each statistical distribution was arbitrarily assigned a value of 100 per cent., and the other averages within the same statistical distribution were assigned proportionate percentage values. For example, in Fig. 1, the peak of the distribution occurred at ages 40 to 44, inclusive. At this latter age interval the average number of books per author was .1004. In Fig. 1 the decimal .1004 is plotted therefore as 100 per cent. At the age interval 65 to 69, inclusive, the average number of books per author was .0125. This latter decimal fraction is equivalent to 12 per cent. of the maximum production (12 per cent. of .1004) and in Fig. 1 the decimal .0125 is therefore plotted as 12 per cent. The foregoing procedure offers several advantages and it presents no serious disadvantages if the method of plotting is borne in mind when interpreting the graphs.

[7] At the time of publishing the second part of "Faust" Goethe was 81 years of age. This chronological age is 3.56 standard deviations above the mean of the statistical distribution that is pictured in Fig. 1.

that picture the very best work to descend most rapidly with advance in age. Thus, from ages 55 to 70 the curve for books which were placed on 12 or more best book lists falls off more rapidly than does the curve for books which were placed on only 8 or more lists. And the curve for books which received 8 or more endorsements falls off slightly more rapidly than does the curve for books which received only 6 or more endorsements. This tendency for very superior publication to cease at slightly younger chronological age levels than does publication of somewhat lesser merit will receive later comment.

An Author's One Best Book

Fig. 3 sets forth the chronological ages at which certain noted authors first published their one best book. In obtaining data for the construction of this figure it was assumed that the one title by a particular author which appeared most frequently on the best book lists was that author's best book. Several other rules were adhered to in making the selections. For example, authors who published no book which received as many as 4 endorsements were omitted. Other writers were omitted when two or more of the books on their lists were tied for first place. In such instances it was not possible to select the author's *one* best book.

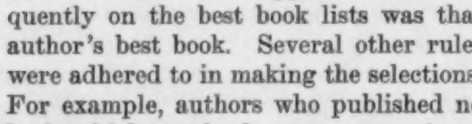

Fig. 3. Chronological ages at which 241 noted authors first published their one best book, and chronological ages at which 80 more highly noted authors first published their one best book.

By means of the procedure that is described in the preceding paragraph the following data were obtained for Fig. 3: (1) The chronological ages at which 80 authors first published what is probably their one best book, each of the 80 titles having been endorsed 8 or more times, and (2) the ages at which 241 authors first published their one best book, each of the 241 books having received 4 or more endorsements. In Fig. 3 both curves attain their peaks at the age interval 35 to 39, inclusive. And the curve for the better books (those of Grade 8) rises more slowly and falls off more rapidly than does the curve for books of Grade 4.[8] This phenomenon again suggests that the very best books tend to be published during a somewhat narrower span of life than do the aggregate thereof.

Long-term Best Sellers

Best sellers are not necessarily best books. Nevertheless, best sellers that maintain their popularity over a long period of time are books that make a strong appeal to humanity in general. Therefore, it will probably be granted that, even though best sellers are not

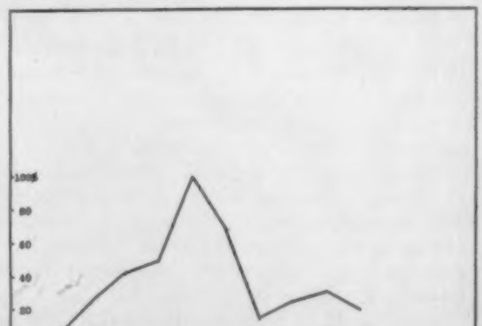

Fig. 4. Average number of best sellers by authors during each five-year interval of their lives. This graph presents data for 47 authors, who wrote 60 books, each of which have had sales of more than 500,000 since 1875.

[8] "Grade 8" books are those which appear on 8 or more of the best book lists studied by Dickinson; "Grade 4" books are those which appear on 4 or more of the best book lists.

necessarily best books, long-term best sellers are worthy of study. What are the chronological ages at which authors have most often produced long-term best sellers?

In *The Publishers Weekly* for April 21, 1934, Mr. E. A. Weeks[9] lists 65 books, each of which have had sales of more than 500,000 copies since 1875. Some of the books that are included in the Weeks list have achieved scores of editions; some of them have been printed and sold by the million. Fig. 4 sets forth the ages at which 47 different authors first published 60 of the 65 best sellers that are listed by Weeks.[10] In proportion to their numbers, authors publish long-term best sellers most frequently when they are not more than 40 to 44 years of age.[11] Note the phenomenal descent of this curve from ages 42 to 52! To what is this very marked descent to be attributed?

Best Books by Women

Lists of best books by women writers have not often appeared. In 1933, however, a committee acting for the National Council of Women of the United States published a list of best books by American women.[12] What were the chronological ages at which these American women first published[13] their best books? Fig. 5 presents the data. Because of the small

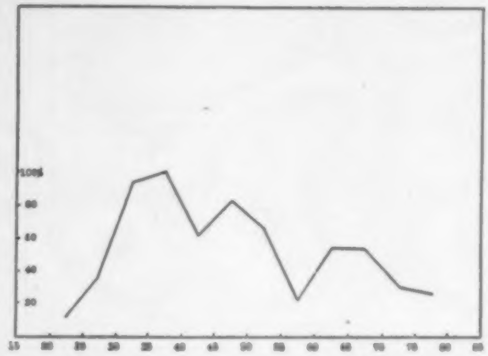

Fig. 5. Average number of best books by American women during each five-year interval of their lives. This graph is based upon date of first publication of the 100 best books by American women during the past 100 years 1833–1933. (Many of the authors are still living.)

number of women authors that would otherwise have been available, it was necessary in the construction of Fig. 5 to include data for a number of living writers. In Fig. 5 the peak of the curve occurs at ages 35 to 39, inclusive.

Appraisal of the Works of Contemporary Writers

The Committee on College Teaching of the National Council of Teachers of English recently prepared a list of best books.[14] Some of the authors of these latter books are still living; many of them are long since deceased. Data were available for 337 books by 203 deceased authors and for 396 books by 285 living authors. The average number of books per author was practically the same for the two groups, namely, 1.39 and 1.66. Fig. 6 reveals that, as compared with the age-curve for the deceased, the curve for the living writers tends to ascend somewhat more slowly and it tends also to sustain itself longer at the older age levels.

Fig. 6 conveys the suggestion that

[9] Edward A. Weeks, *The Publishers Weekly*, 125: 1503–1507, 1934.

[10] For the five other books that were listed by Weeks, dates of first publication were not available.

[11] Data for a few living authors were employed in the construction of Fig. 4. In this instance the utilization of such data was thought to be allowable, since the large sale of the books is already an accomplished fact.

[12] Anita Browne (*Chairman*), "The One Hundred Best Books by American Women During the Past Hundred Years: 1833–1933." Chicago: Published by Associated Authors Service. 1933. Pp. 128.

[13] In this manuscript the words "first published" refer not to a given author's first publication but to the year during which a given book first appeared in print.

[14] Atwood H. Townsend (*Chairman*), "Good Reading." Prepared and published by the committee on College Reading, for the National Council of Teachers of English. New York: Copyright by the Committee. 1935. Pp. 79.

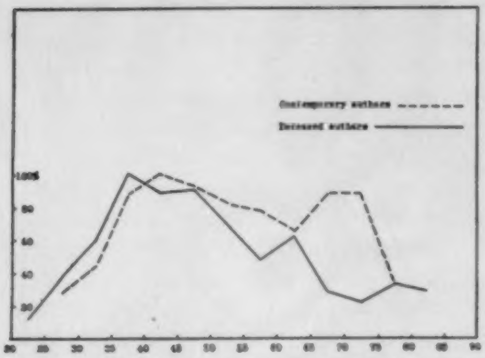

FIG. 6. AVERAGE NUMBER OF BOOKS "WORTH KNOWING" WHICH WERE PUBLISHED DURING EACH FIVE-YEAR INTERVAL (1) BY LIVING AUTHORS, AND (2) BY DECEASED AUTHORS.

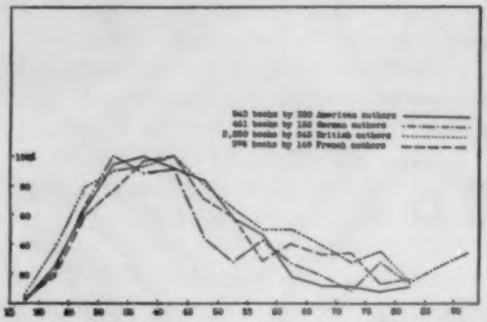

FIG. 7. CHRONOLOGICAL AGES AT WHICH THE MORE NOTED AUTHORS OF FOUR COUNTRIES FIRST PUBLISHED THEIR MORE SIGNIFICANT LITERARY WORKS. THIS GRAPH IS BASED UPON DATA FOR 149 FRENCH AUTHORS, 152 GERMAN AUTHORS, 543 ENGLISH AUTHORS AND 330 AMERICAN AUTHORS.

superior books that are written by young living authors (who are likely to be unknown) tend to be rather slowly recognized. On the other hand, the writings of older living authors (who more frequently have established their reputations) tend to be overrated. If we accept the judgment of posterity as the more valid criterion, it seems probable that a halo effect influences appraisal of the works of older living authors more frequently than it influences evaluation of the works of deceased writers. Possibly this phenomenon helps to explain why investigators have often failed to discern the very marked age differences that exist with reference to the writing of best books.

SELECTIVE BIBLIOGRAPHIES

In preparing lists of allegedly superior literary works, some compilers list practically everything that a given author has published. Other compilers carefully avoid completeness and pride themselves on the fact that their bibliography is really selective. What is found when data are procured from bibliographies that vary widely in the degree to which they are selective?

Fig. 7 sets forth for four national groups the average number of books that were published per five-year interval when the data are obtained from truly selective bibliographies.[15, 16, 17, 18] Fig. 7 presents graphically the following data:

Nationality of authors	Source of data	No. of books	No. of authors	Average no. of books per author
American	Fullerton	843	330	2.55
German	Priest	461	152	3.03
British	Ryland	2,250	543	4.14
French	Butler	376	149	2.52

Each of the bibliographies employed for obtaining the data set forth in Fig. 7 contains an average of less than 5 books per author. Notice that the resultant age curves are fairly consistent for the four national groups.[19]

[15] B. M. Fullerton, "Selective Bibliography of American Literature: 1775–1900." New York: William Farquhar Payson. 1932. Pp. xii + 327.

[16] G. M. Priest, "A Brief History of German Literature." New York: Charles Scribner's Sons. 1909. Pp. xii + 366.

[17] Frederick Ryland, "Chronological Outlines of English Literature." London: Macmillan and Company, 1910. Pp. xii + 351.

[18] K. T. Butler, "A History of French Literature." London: Methuen and Company, Ltd., 1923. In two volumes. Pp. xiii + 496; viii + 395.

[19] The data for the British authors were subdivided into four groups on the basis of the periods when the authors were born. The curves

Less Discriminating Bibliographies

What type of curve is obtained when data are secured from bibliographies that are much less selective? Fig. 8 sets forth data that were obtained from four bibliographies which vary widely in the degree to which they are selective.[20, 21, 22, 23] In each instance, the more selective the bibliography, the more rapidly does the resultant age-curve descend after the age interval 40 to 44 is reached. One can easily understand why the curves that picture a larger number of books per author tend to remain high at most age levels. It requires many years of effort to produce large numbers of books. But why do the peaks of production for the more carefully selected titles occur so consistently *before* rather than *after* age 45?

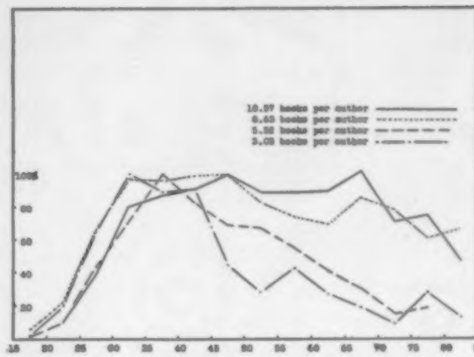

Fig. 8. Age curves obtained from bibliographies which vary as regards the extent to which they are selective.

Quality versus Quantity

Some may wonder whether the differences in the shapes of the curves of Fig. 8 may not be due in part at least to the fact that different groups of authors wrote the books that were used as a basis for constructing the curves. The available data seem to indicate that the foregoing explanation is inadequate. For example, in Fig. 9 the solid line sets forth the chronological ages at which 152 German authors first published 461 of their best works, the latter being found in a highly selective bibliography which lists an average of only 3.03 works per author. The dash line in Fig. 9 presents, on the other hand, the ages at which *the same 152 German authors* first published an aggregate of 2,935 literary works,[24] the average number of works per author being 19.31. In Fig. 9 the dash line might be said to reveal *quantity* of production; the solid line reveals on the other hand *quality* of production.

In Fig. 9 the curve for the production of the better books ascends slightly more slowly than does the curve for the aggregate. This phenomenon suggests the ex-

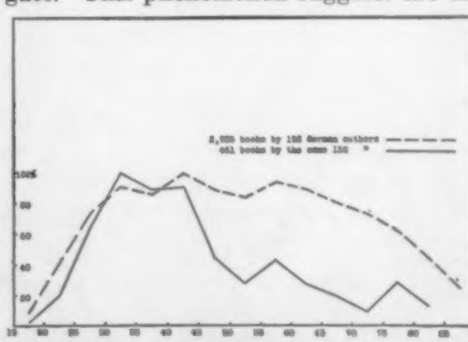

Fig. 9. The solid line sets forth the average number of their best works that were published by 152 German authors during each five-year interval of their lives. The dash line reveals how these same 152 German writers continued to publish.

that were constructed with each of the four sets of data exhibited marked similarity both to the curves that are shown in Fig. 7 and to one another. It seems evident that the data which were employed for constructing the age-curve for the British authors possess internal consistency.

[20] G. M. Priest, "A Brief History of German Literature." New York: Charles Scribner's Sons. 1909. Pp. xii + 366.

[21] Stanley J. Kunitz, "Authors To-day and Yesterday." New York: The H. W. Wilson Co., 1933. Pp. vii + 717.

[22] Paul Harvey, "The Oxford Companion to English Literature." Oxford at the Clarendon Press. 1933. Pp. viii + 864.

[23] S. L. Whitcomb, "Chronological Outlines of American Literature." New York: The Macmillan Co., 1906. Pp. xi + 285.

[24] Wilhelm Kosch, "Deutsches Literatur-Lexikon: Biographisches und Bibliographisches Handbuch." In Zwei Bände. Halle: (Saale) Max Niemeyer Verlag. 1927.

istence of a brief practice period. During this practice period books are being written, but posterity seems not to regard these earliest productions as great books. It seems apparent also that, although the 152 German authors continued to publish during their later years,[25] their later works are less likely to be included in highly selective bibliographies than are the works that were published by them at somewhat younger ages.

In Fig. 10 a similar situation is found to exist. In this figure the solid line presents the chronological ages at which 65 contemporary British and American authors first published 154 starred books. The data used in the construction of Fig. 10 were obtained from two books by Manley and Rickert[26,27] of the University of Chicago. These compilers have indicated the contemporary books which they regard as most outstanding by means of stars or asterisks. The dash line in Fig. 10 sets forth, for the same 65 contemporary authors, the chronological ages at which they first published 1,277 works; the latter figure includes both starred and unstarred publications. Fig. 10 suggests once again that the very best examples of belle lettres are likely to be published during a somewhat narrower span of years than are works of lesser merit.

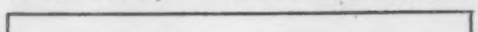

FIG. 10. AVERAGE NUMBER OF "STARRED" BOOKS (AND AVERAGE NUMBER OF BOTH STARRED AND UNSTARRED BOOKS) PUBLISHED BY CONTEMPORARY BRITISH AND AMERICAN AUTHORS DURING EACH FIVE-YEAR INTERVAL OF THEIR LIVES. DATA FROM MANLEY AND RICKERT.

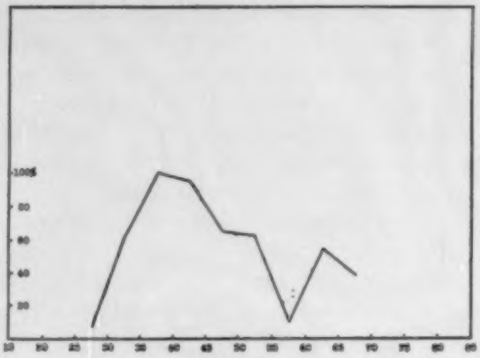

FIG. 11. DATA FOR THE 25 MOST INFLUENTIAL BOOKS PUBLISHED SINCE 1885. ESTIMATES MADE BY EDWARD WEEKS, JOHN DEWEY AND CHARLES A. BEARD. EACH BOOK HAS BEEN COUNTED AS OFTEN AS IT WAS LISTED.

THE MOST INFLUENTIAL BOOKS SINCE 1885

Separate lists of what they believe to be the 25 most influential books that have been published since 1885 have been prepared recently by E. A. Weeks, by John Dewey and by Charles A. Beard.[28] When each book is credited as many times as it was endorsed by the three judges, Fig. 11 is obtained. In Fig. 11 the peak occurs from ages 35 to 39 inclusive.

CONCLUDING REMARKS

The chronological ages at which men have most frequently published books that are good and that are permanently great can be ascertained by assembling data, separately for the various age groups, and by scrutinizing the performance record of each age group. In making such a study it is desirable to utilize

[25] This finding suggests that the decline in the quality of their writing at the older age levels was not due to obvious bodily infirmities or to gross physical weakness.

[26] J. M. Manley and E. Rickert, "Contemporary British Literature." New York: Harcourt, Brace and Co., 1928. Pp. 345.

[27] J. M. Manley and E. Rickert, "Contemporary American Literature." New York: Harcourt, Brace and Co., 1929. Pp. viii + 378.

[28] Edward A. Weeks, *The Atlantic Monthly*, 155: p. 28, 1935.

TABLE I

SUMMARY OF FINDINGS WITH REFERENCE TO THE PRODUCTION OF BEST BOOKS

Data used in	Source of data	No. of books	No. of authors	Average books per author	Median age	Mean age	Standard deviation	Years of maximum productivity
Fig.	1—Dickinson	224	101	2.22	43.50	43.51	10.03	40–44
Fig.	2—Dickinson	111	54	2.06	43.00	42.34	9.60	40–44
Fig.	2— "	224	101	2.22	43.40	43.51	10.03	40–44
Fig.	2— "	366	169	2.17	43.96	44.10	11.15	45–49
Fig.	2— "	532	265	2.01	43.80	44.45	11.40	40–44
Fig.	3—Dickinson	241	241	1.00	44.50	44.62	11.25	35–39
Fig.	3— "	80	80	1.00	42.93	44.19	10.28	35–39
*Fig.	4—Weeks	60	47	1.28	42.20	42.25	9.60	40–44
*Fig.	5—Browne	97	101	0.96	41.50	43.94	13.98	35–39
Fig.	6—Townsend	337	203	1.66	44.09	45.11	12.35	35–39
*Fig.	6—Townsend	396	285	1.39	42.88	44.76	10.80	40–44
Fig.	7—Fullerton	843	330	2.55	39.39	40.63	11.00	35–39
Fig.	7—Priest	461	152	3.03	38.90	40.31	11.73	30–34
Fig.	7—Ryland	2,250	543	4.14	41.47	42.03	13.20	40–44
Fig.	7—Butler	376	149	2.52	41.19	42.66	12.30	40–44
Fig.	8—Priest	461	152	3.03	38.90	40.31	11.73	30–34
*Fig.	8—Harvey	673	122	5.52	41.33	42.92	12.45	35–39
*Fig.	8—Whitcomb	1,157	134	8.63	44.28	46.34	14.85	45–49
Fig.	8—Kunitz	2,191	118	18.57	41.59	43.80	11.70	65–69
Fig.	9—Priest	461	152	3.03	38.90	40.31	11.73	30–34
Fig.	9—Kosch	2,935	152	19.31	44.61	45.25	16.50	40–44
*Fig.	10—Manley and Rickert	154	65	2.37	42.92	44.25	10.70	40–44
*Fig.	10— " " "	1,277	65	19.65	43.50	45.60	13.85	40–44
*Fig.	11—Weeks	71	46	1.54	44.00	44.40	9.65	35–39

* Data for some living authors are included in these curves.

the evaluations of specialists, of literary critics and historians. In the investigation that is reported herein, the writer has adhered to the foregoing postulates. He has accepted the judgment of specialists who published their evaluations under their own names and who must therefore have felt some responsibility for making just evaluations.

The assembled data suggest that literary masterpieces of the first rank have been published most frequently by men who were not over 45 years of age at the time their best books appeared in print. For six age-curves that are based upon highly selective bibliographies maximum productivity occurs at age 37; for eight other such curves the peaks occur at age 42. But the foregoing figures are based upon the dates on which best books were first published. Books must be written before they can be published. And an author sometimes encounters difficulty and delay when trying to find a publisher. The dates of first publication therefore fail to tell the chronological ages of the authors at the time they were writing their best books. Because of the prodigious labor that such a task would entail, the present writer has not attempted to ascertain dates of composition for all the best books that have been studied herein. However, a few dates of composition are available. Although fragmentary, these data make it seem highly probable that best books have been *written* most frequently by authors who were still in their *thirties*.

There are of course many exceptions to this latter statement, and there seems

TABLE II

AVERAGE NUMBER OF CONTRIBUTIONS PER FIVE-YEAR INTERVAL*

		Chronological age interval														
		15–19	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65–69	70–74	75–79	80–84	85–89
————	Fig. 1..		.008	.034	.049	.073	*.100*	.091	.056	.043	.025	.012	.005	.—	.015	
————	Fig. 2..		.007	.030	.064	.057	*.105*	.097	.057	.024	.012	.010	.—	.—	.034	
— - — - —	Fig. 2..		.008	.034	.049	.073	*.100*	.091	.056	.043	.025	.012	.005	.—	.015	
— — — —	Fig. 2..		.007	.039	.052	.067	.081	*.082*	.051	.042	.032	.028	.007	.—	.017	
············	Fig. 2..		.007	.030	.052	.063	*.075*	.072	.044	.039	.033	.027	.011	.003	.011	
————	Fig. 3..		.003	.014	.026	*.036*	.034	.036	.021	.022	.015	.015	.005	.—	.006	
— — — —	Fig. 3..		.003	.010	.020	*.046*	.041	.035	.020	.019	.016	.009	.006	.—	.—	
————	Fig. 4†.		.004	.021	.034	.040	*.081*	.055	.011	.019	.024	.015	.—	.—	.—	
————	Fig. 5†.		.004	.014	.036	*.038*	.023	.031	.025	.009	.020	.020	.011	.010	.—	
————	Fig. 6..		.007	.024	.037	*.063*	.055	.056	.042	.029	.038	.017	.013	.020	.018	.057
— — — —	Fig. 6†.		.—	.018	.029	.060	*.068*	.062	.055	.052	.043	.059	.058	.021	.—	
————	Fig. 7..	.001	.023	.060	.092	*.097*	.089	.081	.055	.045	.018	.011	.010	.007	.009	
- — - — - —	Fig. 7..	.003	.025	.081	*.124*	.110	.113	.056	.035	.053	.033	.024	.011	.035	.016	
············	Fig. 7..	.007	.050	.106	.123	.128	*.137*	.111	.087	.069	.068	.054	.037	.047	.019	.033‡
— — — —	Fig. 7..	.003	.016	.055	.072	.090	*.093*	.066	.054	.027	.037	.031	.032	.012	.015	
- —— - ——	Fig. 8..	.003	.025	.081	*.124*	.110	.113	.056	.035	.053	.033	.024	.011	.035	.016	
— — — —	Fig. 8†.	.003	.023	.097	.161	*.227*	.188	.157	.151	.125	.092	.069	.034	.043	.—	
············	Fig. 8..	.015	.055	.158	.232	.230	.236	*.239*	.198	.178	.164	.206	.187	.145	.157	.118
————	Fig. 8†.	.—	.087	.331	.683	.738	.771	.851	.760	.760	.762	*.861*	.606	.636	.400	
————	Fig. 9..	.003	.025	.081	*.124*	.110	.113	.056	.035	.053	.033	.024	.011	.035	.016	
— — — —	Fig. 9..	.045	.211	.383	.475	.448	*.522*	.463	.439	.490	.463	.420	.383	.317	.226	.125
————	Fig. 10†.			.040	.062	.075	*.111*	.077	.061	.081	.096	.035	.022			
— — — —	Fig. 10†.		.055	.246	.542	.617	*.752*	.716	.619	.733	.536	.435	.261	.304	.375	
————	Fig. 11†.			.004	.044	*.072*	.068	.047	.045	.006	.040	.027	.—	.—	.—	

* The peak of each statistical distribution is italicized.
† Data for some living authors are included in these distributions.
‡ The average for the succeeding five-year interval, namely, for ages 90 to 94 inclusive, is .050.

to be no fixed age limit beyond which outstanding literary work can not be done. Perhaps it will be better for us to discard the habit of thinking in terms of age limits or even in terms of average ages. The creative years may be envisaged best not by reference to a simple average or to an age-range but rather by study of age-curves (or statistical distributions) which reveal trends and probabilities rather than fixed age limits.[29] Certainly, some writers have produced great books at relatively advanced ages. However, this phenomenon is not a frequent occurrence, and those who are much impressed by the fact that the second part of Goethe's "Faust" was first published when Goethe was more than 80 years of age should recognize that such an occurrence is not at all typical but most unusual.[30]

[29] Unfortunately, only a very small number of such age-curves are available.

In attempting to interpret the age-curves that are presented herein the present writer has questioned several experts whose judgment should merit careful consideration. A copy of Fig. 9 was sent to an eminent literary historian. The historian was asked whether it did not

[30] Although Part II of Goethe's "Faust" is cited frequently as proof of the fact that men of advanced years are capable of producing excellent literature, it is worthy of mention that Part I of "Faust" is more often *quoted* as an example of excellent writing. Moreover, the following remark by a widely known scholar whose name appears in the bibliography of this article is of interest. "Many literary historians think that the works which Goethe wrote between 1770 and 1780 [ages 21 to 31] were never equalled by him later, an opinion which can be defended effectively."—Unpublished personal communication.

seem preposterous that in Fig. 9 the peak for quality of production appears earlier than the high point for quantity of production. In commenting upon Fig. 9 the literary historian stated that he was not surprised at this finding. On the contrary, he expressed surprise at the surprise of the present writer. His statement follows:

> The surprise which you express in your letter of Feb. 14th "that *quality* of output precedes *quantity* of output" surprises me in turn. I can easily believe that this finding is a valid one. . . . It is normal and natural that a young man has much more mental and physical energy than later on in his life. He often feels himself the bearer of an epoch-making message and therefore proceeds to the expression of his message with all the intense conviction and concentration of a gifted youth. Very soon, however, that fire dies down, at least to some extent, and his later works reveal perhaps that he was a man of a single message, in any case that he has grown steadier, more restrained and consequently more prosaic and probably duller. . . . I have come to this conclusion largely on the basis of my study of biography.

Do the decrements at the older chronological age levels imply a corresponding decrement in the *ability* to write best books? There are at least two excellent reasons for rejecting this hypothesis. In the first place, the *post hoc ergo propter hoc* fallacy should be avoided. Secondly, we are dealing here not with sheer ability but with actual concrete performance. It seems obvious that outstanding potential ability must be present in the individual who produces literary masterpieces. It is by no means clear, however, that failure to produce is due necessarily to inability to produce. We know only that, for some one or more reasons, the noted authors, although they continued to write, failed to produce best books as frequently at the older as at the younger age levels. Probably most students of psychology would agree that such a complex behavior as the production of best books is due to numerous causal factors. The decrement at the older age levels might be due therefore to any one or more of a very large number of possible causes.[31]

For most readers it will not be necessary to state that psychology has no fault to find with the gifted writers because these writers failed during their later years to maintain the quality of their writing. Students of human behavior are interested primarily in acquiring a better understanding of their subject-matter. With this end in view they endeavor to assemble trustworthy and significant behavior data. It would be puerile for psychologists to find fault with the behavior which they are seeking to understand. Probably no psychologist would assert that authors exist for the sole purpose of producing best books. Certainly, the present writer harbors no such belief.

[31] The fact that most of the authors continued to write during their later years indicates that they had not lost all desire to write. On the other hand, they may not have been maximally motivated during their later maturity. Possibly something akin to the law of diminishing returns may have been operating at this time. *Cf.* in this connection Thorndike's excellent discussion of why adults often fail to continue to learn after they have attained adulthood. See E. L. Thorndike, E. O. Bregman, J. W. Tilton and E. Woodyard, "Adult Learning." New York: The Macmillan Co., 1928. Pp. x + 335.

NATURAL HISTORY EXHIBITS AND MODERN EDUCATION

By Dr. ROBERT CUSHMAN MURPHY
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LORD GREY of Fallodon once remarked, during a visit to the American Museum of Natural History, "I would gladly cross the ocean for the sake of four hours in this institution."

The enthusiastic comment relates obviously to the museum's exhibits, which, although far from constituting the whole organization, take first place in the conception of any public museum. From an analysis of the budget of the American Museum throughout several years, it appears that two thirds of every dollar spent go toward the creation and maintenance of exhibits, the remaining third being divided between research and other activities.

It scarcely needs pointing out that contemporary museums face wide-spread competition in their own field of exhibition. We live in an age that broadcasts its messages largely by the graphic method—by display in one form or another. Fairs, visual demonstrations in schools and, perhaps most of all, the design and content of what is shown behind an infinity of smart shop windows, all present challenges that the museum must take into account. Exhibits planned in the year 1869, when the American Museum was founded, could hardly interpret the natural history of to-day.

What, then, are the essentials in method for a modern natural history museum? A great financier, who was also one of the founders of the American Museum, once made a classic reply to a question put to him in court by stating disarmingly that character is the basis of credit.[1] The basis of museum exhibits might be defined, slightly less tersely, as scholarship in conception and technique in execution. Scholarship must rest, of course, with the scientific staff. As regards technique, it is well known that the exhibits occupying so many acres of floor space depend upon the talent and painstaking labor of a long roster of trained men and women, who include painters, sculptors, engineers, workers in metal, blown glass and various plastic materials, tanners, taxidermists and artisans possessed of phenomenal capacity to make faithful copies or scale models of all manner of natural objects. At a recent meeting in the office of the mayor of New York, attention was called to the fact that the city's natural history museum has a much larger working force than a great sister institution devoted to the fine arts. In eight words of one syllable, the director of the American Museum precluded any possible implication of an unjust disparity. His comment was, "They buy their art; we must *make* ours."

If one were to analyze the character of exhibits in a natural history museum, a trifold division might be made, although the border line separating any of the three would be necessarily somewhat vague. In the first place, there are on view many objects, or representations of normal phenomena, which are primarily of intrinsic interest. They are in themselves perennially exciting and stimulating in varying degree. A few random examples of such are the following:

The bench mark of the United States Geological Survey which indicates to a fraction of second the geographic position of a particular point on the surface of the globe, and its altitude to the hundredth part of a foot above sea level.

[1] J. Pierpont Morgan, 1837–1913.

The north and south polar sledges of Peary and Amundsen, respectively.

The cross section of the California Big Tree. (The historical commentary forming part of this exhibit brings it also into the third group, discussed below.)

The skeleton of Brontosaurus, mightiest of dinosaurs.

The model of the Blue Whale, a present-day mammal far larger than any known prehistoric creature.

The 579 pound shell of a mollusk, Tridacna.

The reconstruction of the Dodo.

The Easter Island stone figure.

The tatooed Maori heads, which at once repel as grim trophies of barbarism and attract as examples of amazing design.

The Drummond amber.

The Cape York meteorites.

All such factual exhibits as these arouse a host of unguessed ideas that reverberate through the corridors of countless minds. The effect of each is, however, unplanned and unpredictable, and each is shown chiefly for its own sake. Can such exhibits be called static? Far from it, partly because there are no known limitations to the responses aroused by such unelaborated expressions of truth and, furthermore, because there are endless successions and generations of new eyes to perceive them.

A second group of museum exhibits might be classified as of primarily *timely* interest, that is, as connected with current news. At intervals of years, the reservoirs supplying water to the metropolis become infested with a microorganism that imparts a harmless but unpleasantly fishy odor to the indispensable fluid that flows from our taps. Human memory is short, besides which there are hundreds of thousands of newly arrived or newly grown-up urban residents to become alarmed. The press, fortunately, merely has to consult its old files in order to explain the recurrent circumstances. The glass model of *Synura uvella,* a colonial flagellate enlarged ten-thousand-fold, is brought from its systematic position in the Darwin Hall, is given a temporary place of honor near the main entrance of the museum and is inspected by thousands of visitors, who at other times might pass it by with no more than a casual glance. Their edification, incidentally, relates not merely to the transitory phenomenon of fishy drinking water, but also to rhythmic cycles in biological productivity, to the power of infinitesimal specks to multiply into cubic miles of protoplasmic jelly, and to the microcosm of life whose universe may be a drop of water.

Many other exhibits of the moment have given evidence of their importance. The news that the average citizen reads in his morning paper sometimes provides the museum with opportunities not attainable through any deliberate campaign, regardless of the energy and funds put into it. Such are to be seized upon as educational windfalls. Nor has the opportunity yet been more than barely tapped, for additional temporary exhibits might well be tied up with such manifestations of an outraged nature as the great river floods of 1937. How more effectively could we spread a knowledge of the projects by means of which Americans must repair the damage they themselves have wrought, if civilization is to endure in this potentially richest of temperate continents?

Finally, we come to a consideration of the class of museum exhibits that involves the major thought of members of the staff, namely, those planned to impart to visitors an organized system of information. In these the principle to be elucidated transcends the interest of the objects themselves. The latter are bricks in the structure, and the stated aim is to build a museum of ideas rather than of things. While these are usually known as "permanent" exhibits, many of them are properly subject to constant change. They are in essence dynamic, and, as the emphasis in various branches

of natural history has transformed throughout the decades, so has their museum interpretation correspondingly developed. To the complaint of a member that, during her somewhat infrequent visits to the American Museum, the special halls that she wished to inspect had an aggravating way of being "under repair," the director replied that her charge was a compliment. Would she, he asked, like to believe that her museum was a frozen institution, and that cases arranged in 1930 could do full justice to the status of knowledge five years later?

The American Museum's interpretative exhibits range from very simple associations of objects or organisms to others that might prove within the grasp only of persons of considerable education and discernment. *Persicos odi, puer, apparatus!* Museum exhibits should certainly never be more abstruse or complex than absolutely necessary, but neither should they be limited to the primer stage of science. The latter restriction would be as unreasonable as confining a musical program to the level of the poorest tastes in the audience. We must provide in our museum plan for the highest order of intelligent and inquiring laymen, including those whom William James would designate as the truly "tough-minded."

First and most widely advertised among natural history displays illustrating an association of ideas are, of course, the habitat groups. Once installed, these are rarely altered, although many have been replaced. The conception of such exhibits did not originate in this country, but they have undergone here their fullest development. Incidentally, the earliest example in the United States—a family of robins nesting in a spray of apple blossoms—forms a still effective item in the American Museum. It is a far cry, indeed, from such a simple installation to the great exhibits of the Coral Reef, the Gorillas of Mount Kivu, the Navajo Indians and their ceremonies, or the fifteen miniature earth-sections in the form of block models which reveal the physiography and geologic history of as many parts of North America.

The aims of a habitat group go beyond the reconstruction of a "pretty picture" transferred behind glass from the outer world. Its purpose ought also to be ecologic, that is, it should elucidate natural interrelationships between organism and organism, and between all and the physical environment. It may deal further with a combination of many other things —with the life story of both plants and animals, or even of minerals which also have birth, existence and death, with geographic zones, conservation, biological adaptation, with history, folklore and a wealth of other ideas. Let us cite examples:

Perhaps more visitors to the American Museum ask to have the nightingale pointed out than is true of any other single bird. They can now be best satisfied through the habitat group of English bird life. Here, among the beeches, holly, gorse and bluebells of the New Forest, sits the storied singer, along with cuckoo and skylark, chaffinch, wood pigeon, rook and jackdaw and a host of others which belong to us by the divine right of literary inheritance. The exhibit is, indeed, a magic casement. The inquiring visitor may learn, furthermore, the importance of vast and ancient trees (which we have so wantonly eliminated from much of our own countryside) with relation to the cubic environment that birds are capable of filling. Here, then, is at least one reason why England has a larger bird population than is to be found in most other temperate lands. One can learn, too, while looking at a British titmouse scarcely distinguishable from our American chickadee, something of the intimate relationships among northern circumpolar forms of life which claim Old and New World alike as their home. At the dedication of this New

Forest group, a delightful suggestion was made by Sir Gerald Campbell. How happy it will be for international neighborliness, he remarked, if among the generations of Americans who will gaze into this Hampshire landscape, with its birds of Chaucer and Shakespeare and Keats, there is now and again one who will be moved to say to himself, "I must cross the ocean soon and find out whether Englishmen are worthy of their birds."

From the universal charm of northern springtime, let us turn to the macabre and unfamiliar fascination of the bottom of the ocean. Two thousand fathoms deep, in the inner sanctum of the hall of fishes, silvery ratfish glide in and out through rotting flesh along the backbone of what was once a whale. What may the least tutored of visitors really carry away from this and adjoining exhibits and their labels? That eternity is as black as pitch in the abyss of the waters; that eyes may avail, nevertheless, because some living beings have evolved their own lanterns of cold light; that all primary sustenance of the depths rains down from layers far above, and that the bottom population is made up wholly of the predatory and cannibalistic; that a permanent temperature of melting ice is of no moment to animals which need no insulation because they have no fixed bodily warmth to maintain; that the enormous and notorious pressures are purely relative and in essence illusory, because the only requirement of wellbeing, even for the most delicate of organisms, is that the internal pressure of its tissues be equal to that of the medium outside.

But habitat groups, however impressive, can not stand as the final goal of exhibition. With the Akeley African hall nearing completion and the Whitney memorial hall under construction, it is likely that the American Museum has already attained the ultimate in elaborate representation of nature in life-size scale. Similar exhibits can be built, but it is hard to believe that the result can be appreciably bettered. The groups now on view or projected no doubt justify their cost and space for reasons already indicated and, even more particularly, because in many instances they alone can provide posterity with realistic glimpses of a primitive world that will be no more. A few of the assemblages of mounted birds and mammals already share at least one thing in common with exhibits, for instance, such as the matchless weaving of the Incas; animals and textiles alike may be said to represent something that is finished, something that can never be replaced; it is only in museums that future generations may seek them.

The need for distinctly new approaches, even in the making of habitat groups, has long been recognized, as witnessed by the American Museum's Rotifer exhibit, which brings to the naked eye the once unimaginable life of a cubic centimeter of pond water enlarged a million times! Into other and even more dynamic rôles of expression, however, the trend in exhibits is fortunately leading us. The "things" shown become increasingly units in a diagrammatic whole. Selected, rather than random, facts are marshalled to point out the significant and omit the trivial. Best of all, there is nothing fixed or sacrosanct about such exhibits; change rather than permanence is their accepted destiny; an arrangement may be scrapped and recast as rapidly as new truths warrant the step.

The exhibits of fossil vertebrates, to choose an example dating from the early years of the American Museum, have always comprised a constantly growing synthesis of ideas, becoming clearer and more meaningful as the strata of past worlds have yielded up their treasure. Little by little the fragments have developed into such wholes as those outlining the evolution and distribution of horse, camel, rhinoceros, titanothere.

The halls are further accented by almost overpowering presences—the rearing skeleton of Tyrannosaurus, the relief model of Baluchitherium. And, finally, the several parts are knit together by the mural paintings which garb primordial bones with the vestments of life and reality. It would be hard to estimate the influence of this single department of the museum upon the outlook of modern man; suffice it to say that such a commonplace vernacular word as "dinosaur" was a highbrow term only a generation ago.

To single out among exhibits a few additional examples that serve particularly well the purpose of current scientific exposition is unfair to a much larger number which must here go unmentioned. It is safe to guess that an independent selection might result in an entirely different choice. The following are a few, listed individually or collectively, large or small in their respective scopes:

The models in the Morgan memorial hall which illustrate the principles of crystallization.

The exhibits which explain the dating of geologic time by plotting the relative thickness of clay varves deposited seasonally during glacial periods. With these might be linked kindred archeological demonstrations of how prehistoric man-made structures have likewise been dated through the study and correlation of annual growth-rings in their ancient timbers.

The several exhibits dealing with the biology of insects and of reptiles and amphibians. These not only explode numerous popular misconceptions but also define with all but wordless simplicity a number of the modes, devices and causal sequences in nature which, under less lucid demonstration, are often difficult to convey or comprehend. Some of these exhibits demonstrate, moreover, the entirely feasible use of living organisms for certain museum purposes.

The introduction to human and comparative anatomy, which begins with the sun and the use of its energy by living beings, and progresses by logical stages to the function of the human brain and the physiology of mental processes.

Numerous ethnographic exhibits, which at once reveal the accomplishments of past or primitive peoples and serve as sources for current art and design or as stimuli which bear in some other way upon contemporary civilization. Here, indeed, are exhibits of ideas which show the place of social habits, on the one hand, and of geographic environment on the other, in determining human culture; which show—to pick at random—the iron technique that distinguishes African Negroes from all other savages; the models that point out the high efficiency in practical navigation attained by the South Sea Islanders; the origin and growth of Central American civilizations wholly independent of those in the Old World.

But, beyond all present accomplishments, we are surely at the threshold of a thousand fresh opportunities in museum development. The exhibition value of many recent discoveries in natural history can scarcely be overemphasized. Where in any museum is there a scale of the universe, or more than passing reference to what has been learned about the chemistry of living substance? Where can we find in graphic form the fundamentals of life in the sea, the principles of animal and plant associations, the physical factors regulating life in the desert or the jungle? Yet such matters can be reduced to terms of simplified description far better in museum exhibits than in books. Furthermore, where in museum treatment is shown the relation of sun-spots and climatic cycles to the growth of living communities, both plant and animal? Or what regulates the size and the length of life of organisms, or the distribution in nature of color and of what we call beauty?

Contemporary study of behavior, aided by the experimental resources of chemistry and biophysics, is outlining a startling and illuminating picture of the animal mind. At the same time, mechanical devices, such as the photoelectric cell, sound photography, "robot-voices"—perhaps even television—are supplying us with able and equally up-to-date means of demonstrating the findings. The halls of natural history museums should and will include ingenious exhibits that can tell us much about how

the external world looks in color, form and the relative importance of its component parts, when viewed by the eye of a bee, a bird or a fox. Related exhibits might show how animals necessarily react with respect to the rhythmic cycle of their endocrine glands. An important supplementary place in exhibition cases will be required, of course, for revealing the experimental studies through which such confident yet seemingly mystical conclusions have been reached by prying man.

Most natural history museums have elementary exhibits dealing with the science of genetics, but where can we look for popular demonstrations of the enormous recent advances in that field, including the subject of induced mutations? Discoveries relating to the biological value of light and of climatic change have found their way into college courses, but thus far only to a negligible extent into museum cases. Many museums have pretty caves among their exhibits, for example, but not yet an explanation of how cave faunas have been moulded by the absence of light. Creditable museum records of early man are numerous, but where can we yet see dramatized the steps through which the glacial period produced modern man? What is intelligence, and does an amoeba possess it? How do insects feel and think? How has man come by his instincts; how and to what extent are these controlled by his newer and rather unstable endowment of higher discrimination? The answers to all such questions lend themselves admirably to museum methods.

All this and much more, indeed, must soon come to pass unless the natural history museum is to fail in fulfilling its service as a modernized beacon lighting the way between the discovery of truth and its widest possible dissemination.

To-day it is increasingly evident that as preparation for happy and well-ordered living the sciences have crowded their way in among the old "humanities" of the classical tradition. Leaving aside every vocational or so-called practical bearing, ignoring even the rich satisfaction that knowledge of the green and vibrant world of nature confers in this out-of-door age—even beyond all this we know that as education which must prepare for an understanding of everyday life, of social organization, of government, the old aspects of truth have become insufficient. The "man in the street" must add to his fund of information at least a minimum knowledge of modern physics and of the miracles of protoplasmic behavior if he is ever to gain an inkling of what life and the cosmos are all about. From the department of astronomy to that of the science of man, natural history museums should still aspire to share and to lead in the great campaign.

Courtesy of C. E. Dutton

CLARENCE EDWARD DUTTON

C. E. DUTTON—EXPLORER, GEOLOGIST, NATURE WRITER

By Dr. WALLACE E. STEGNER
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THE discovery and exploration of the Plateau Province of the Southwest, comprising southern Utah, northern Arizona and portions of eastern Colorado and New Mexico, was the work of many men, most famous of whom are government men likes Ives, Wheeler and Powell, and the "Mormon Leatherstocking," Jacob Hamblin. As is frequently the case, however, men later in time, and with less right to the title of explorer, have left as prominent marks of their personalities and work upon the country as its actual discoverers. The name of Clarence Edward Dutton, for example, is undoubtedly as well known in the history of the opening of the Plateau Province as that of even Powell himself, and yet Major Dutton apparently never discovered anything for the first time.

There are several reasons for Dutton's reputation. In the first place, his work led him, from 1875 to 1887, to five different spots which later became national Parks. What Muir is to Yosemite, Dutton is to Zion and the Grand Canyon. Although other men, notably Ives and Powell, had written interesting accounts of the Grand Canyon, Dutton's "Tertiary History of the Grand Canyon District," appearing in 1882, was the first detailed and extended account of the great gorge, and contained as well the earliest description of Zion except for Powell's brief thumb-nail sketch in his "Exploration of the Colorado River of the West."

Two years earlier Dutton had written, in his "High Plateaus of Southern Utah," a description of Bryce Canyon that considerably amplified the first picture presented by A. H. Thompson in his report affixed to Powell's "Exploration of the Colorado River of the West." Professor Thompson and F. S. Dellenbaugh, apparently, were the discoverers, having seen the amphitheater while searching for a practicable route down the Colorado in 1872. Dutton probably saw the Paria Amphitheater and Bryce for the first time in 1875, his first year in the Plateau Province.

It seemed Dutton's fate, or fortune, consistently to be the second or third into a field, and yet in almost every case his discoveries and scientific studies of causes and meanings were noteworthy. He was the man who pointed out that Mount Lassen was the last locus of volcanic activity in the United States—a statement since borne out by Lassen's later activity. Although he first saw Crater Lake thirty years after its discovery, he was the first man to bring boats in (a feat of almost insuperable difficulty) for the purpose of plumbing and measuring the lake, and his theory of the origin of the crater has by now become almost a truism. It was in 1885, in the company of William G. Steel, later patron of Crater Lake National Park, that Dutton first saw this spot, and a good part of the next field season was spent in detailed measurements and soundings.

Not content with being involved in the early study and history of Zion, Bryce, Grand Canyon, Mount Lassen and Crater Lake National Parks, Dutton in 1882 spent four months with a pack train among the great calderas of Hawaii with the purpose of studying volcanoes in

action before investigating the extinct volcanoes of Oregon and northern California. The resulting monograph, "Hawaiian Volcanoes," although ostensibly a scientific work, is lightened throughout by humorous anecdotes and brilliant descriptive passages, and is one of his most charming books.

Six national parks thus owe something of their history to Major Dutton. All of them, except Mount Lassen, owe him more: the basic geological explanations which are now commonplaces aired by park rangers and guides for the edification of tourists. His books on the Southern Utah Plateaus and the Grand Canyon are still broad foundations for later highly detailed studies, and they remain, despite the passage of more than half a century, the best general works on these regions.[1]

Major Dutton was an explorer of little-known regions and an explorer among little-known facts. Just as his studies among the Plateau regions led to novel geological theories, such as the theory of plural erosion cycles, so the sights which he saw, unusual in the extreme and widely different from the rock formations of other countries, led to a series of unusual names, which, influential as they have been upon the later nomenclature of the region, have been subjected to severe criticism.

Dutton observed, as any one really studying the Grand Canyon and its environs must observe, the striking resemblance which the buttes and towers bear to oriental architecture. Accordingly, when naming points in the gorge, he chose such titles as the Hindoo Amphitheater, the Ottoman Amphitheater, Vishnu's Temple, Shiva's Temple, and so on. It is to Dutton's example that we owe the long series of oriental names that decorate the other canyons, notably Bryce, where the horseshoe is dotted with temples of Osiris and Isis and other eastern gods and goddesses. Thomas Moran followed Dutton's lead in naming the Temple of Set in the Grand Canyon.

Not every one, as has been mentioned, approves of these names. In a letter written just before his death Mr. F. S. Dellenbaugh, a companion of Powell and Dutton on early expeditions and a noted explorer in his own right, had this to say: "I have one grudge against him. He did not believe in applying Indian names to features not already designated—and there were many at that time—as he disliked Indian names. He was thinking, I suppose, of Passamaquoddy and Memphremagog and so on. I argued with him without success, and so he started that series of silly Egyptian and what-not names in the Grand Canyon which are about as inappropriate as any names could be. I don't now remember his argument. He did, however, name Point Sublime, which satisfies me. . . ."

However one may feel in this matter of appropriate nomenclature, one is forced to admit that Dutton's example bore fruit and definitely pinned an oriental atmosphere on the Grand Canyon that will last. The architectural basis for the names is certainly sound, and many of Dutton's other names—The Cloisters, The Transept, Vulcan's Throne, and so on—borrow from other architectures than the oriental ones. He also named a number of the points which jut far out into the gorge and offer the most sublime views. Of these Point Sublime is generally a favorite, as is Point Dut-

[1] This is not to minimize the work of other early geologists. Dutton himself says, in his "Mount Taylor and the Zuñi Plateau," that the geological results are the product of mutual help among Powell, Gilbert and himself. "All observations and experiences were common stock, and ideas were interchanged, amplified, and developed by mutual criticism and suggestion. The extent of my indebtedness to them I do not know. Neither do they. I only know that it is enormous, and if a full liquidation were demanded it would bring me to bankruptcy."

ton, named for the geologist. Cape Royal and Cape Final, as well as Hidden Spring and other spots, received their names from him. Occasionally, as in Smithsonian Butte, near Short Creek, Dutton honored a man or an institution in a place name.

A full list of spots named by Dutton would undoubtedly be long, but until some detailed study of Utah place names is made, it must remain incomplete.

There is one further reason for Major Dutton's lasting reputation in the Southwest. People recognize in him a great geologist and an important explorer, but they recognize even more immediately a great nature writer.

Natural scenery as grand as that of the Plateau Province is difficult to describe accurately and vividly, as hundreds of inept pen-pictures of the Grand Canyon testify. Yet Dutton, in "The High Plateaus" and "The Tertiary History" paints landscapes unforgettable in their detailed charm. He is master of panorama, as indeed he had to be in a country where the range of vision is sometimes a hundred miles and more. No one has ever caught as well as he the broad vistas of torn and twisted and weirdly beautiful desert and badland. No one has ever fused so completely scientific accuracy and literary charm, as Dellenbaugh has said.

In the last analysis it is not essentially as an explorer that Dutton will be known, although he has certainly some right to the name; it is not primarily as a geologist, though he is one of the great ones of early American geology; it is as an interpreter of landscape, a nature writer who combined sound scientific knowledge with a near-genius in words. One thinks of Muir and Burroughs as comparisons. Dutton was more limited in his field than they, but as fine a writer within his limits and a greater scientist than either. It is his versatility, rather than preeminent abilities in one line, that make his name a byword in the Plateau Province.

TRAIL RIDGE ROAD IN THE ROCKY MOUNTAIN NATIONAL PARK NEAR DENVER

A POINT OF SCENIC INTEREST FOR MEMBERS OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE ATTENDING THE DENVER MEETINGS, WHICH WERE ANNOUNCED IN THE JUNE ISSUE OF THE SCIENTIFIC MONTHLY. AT THIS POINT THE ROAD HAS REACHED AN ALTITUDE OF MORE THAN 12,000 FEET. IN THE DISTANCE AND AT THE LEFT, ABOVE THE GREAT CLOUDBANK THAT OBSCURES FOREST CANYON, IS LONG'S PEAK, SENTINEL OF ROCKY MOUNTAIN NATIONAL PARK, WITH AN ALTITUDE OF 14,255 FEET.

THE PROGRESS OF SCIENCE

MEDALLISTS OF THE NATIONAL ACADEMY OF SCIENCES

THE National Academy of Sciences at its seventy-fourth annual meeting from April 26 to 28, 1937, presented four medals in recognition of noteworthy accomplishments in the field of scientific research. The medals were provided from trust funds given to the academy; several of these funds specify that the medal shall be accompanied by an honorarium. The award of each medal is made by the academy in business session on recommendation of the special committee or board in charge of the trust fund. The medal is presented to the recipient at the dinner of the academy at either the annual or the autumn meeting. Before the actual presentation of each medal, the president requests the chairman or other member of the trust fund committee to state briefly the reasons why the recipient was selected for the award.

THE AGASSIZ MEDAL FOR OCEANOGRAPHY

The Agassiz Medal was awarded to Dr. Martin Knudsen, of the University of Copenhagen, Copenhagen, Denmark, "in recognition of his contributions to that field of scientific research, including his report on the hydrography of the Danish *Ingolf* expedition, published in 1898; the preparation of his 'Hydrographic Tables,' published by the International Council for the Exploration of the Sea; his inauguration of standard sea water distributed to other oceanographic institutions by the International Council for the Exploration of the Sea; his invention or improvement of the designs of oceanographic instruments, and his leadership in the development of precise methods in the study of physical oceanography."

Dr. T. Wayland Vaughan, chairman of the Murray fund, which recommended the award of the Agassiz Medal for oceanography to Dr. Knudsen, stated in his presentation speech that

> Progress in many branches of science depends upon the possession of adequate instruments, a body of established physical constants, and proper procedure. The mere recognition of a scientific problem will not solve that problem. Knudsen's first oceanographic experience made him keenly conscious of the fundamental needs of physical oceanography and he set about the development of apparatus and the determination of physical constants. His invention of standard sea water and his refinements of chlorine titration for the determination of the salinity and density of sea water over the entire range of temperatures encountered in the ocean, and the tables prepared by him to embody the results of long-continued investigations, constitute a foundation stone of modern dynamical oceanography.
>
> Knudsen has made a number of designs of oceanographic apparatus, such as a frameless water-bottle, a bottom-samples for hard bottoms and a spectrophotometer. He has also paid fruitful attention to a number of oceanographic problems. His first papers were on the influence of plankton on the quantities of oxygen and carbonic acid dissolved in sea water. His researches in the field of low pressure phenomena in gases are better known to physicists than to oceanographers.
>
> The members of the committee that nominated Professor Knudsen for the Agassiz Medal are happy that the academy approved its recommendation. Professor Knudsen richly deserves the honor conferred upon him.

Dr. Knudsen was unfortunately unable to receive the medal in person, and Mr. Otto Wadsted, envoy extraordinary and minister plenipotentiary of Denmark, accepted it gratefully for transmission to Dr. Knudsen through diplomatic channels.

THE HENRY DRAPER MEDAL

The Henry Draper Medal was awarded to Dr. C. E. Kenneth Mees, director of the Research Laboratories of the Eastman Kodak Company, Rochester, N. Y., "in recognition of his investigations in photographic processes which have given

emulsions sensitive to the red and infrared of the spectrum and made possible the recent great advance in knowledge of this highly important region of the radiant energy of the stars."

The presentation speech was to have been made by Dr. V. M. Slipher, chairman of the committee of the Murray fund; but he was unable to be present and Dr. Frank Schlesinger, of Yale University, presented a digest of Dr. Slipher's statement:

Dr. Mees has devoted his life to the development of the theory and the perfection of photographic processes and materials. His early prominent piece of work, "Investigations on the Theory of the Photographic Processes," published in 1907 in collaboration with Sheppard, has since been a classic on the subject. This gave him wide distinction, and he was called to America in 1912, where since then he has been continuously occupied in this field of endeavor at the Eastman Kodak Research Laboratory, of which he has been the director.

Let us recall that at the beginning of the present century it was hardly possible in astronomy to photograph a spectrum range of more than about 2,700 Angstrom units, *i.e.*, from 3,300 to 6,000 A. But to-day fully twice that length of spectrum (*i.e.*, from 6,000 to 12,000 A. in the infra-red) has been added. Much of this great gain has resulted from the development of emulsions and sensitizers at the hands of Dr. Mees. His wide extension of the photographable spectrum into the longer wave-lengths carries even greater scientific importance than might at once be evident, for it brings us knowledge of a vast new portion of the energy of the stars. And this means our knowledge of the heavenly bodies may now be builded upon this broader foundation. In accomplishing these and other advances for photography our medalist has contributed to the general progress of science, as well as to astronomy in particular. Incidentally he has built up the excellent Research Laboratory of the Eastman Kodak Company. Thus for thirty years he has carried on with marked ability and skillful technique fundamental researches.

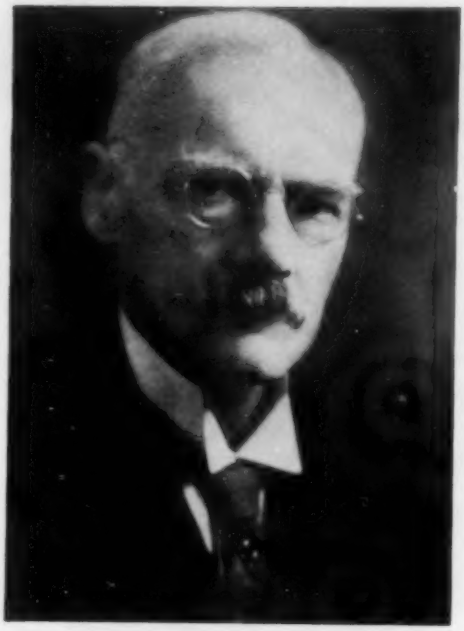
It is, therefore, a pleasure, on behalf of the Draper Committee, to present Dr. C. E. Kenneth Mees for the high honor of the Henry Draper Award.

DR. C. E. KENNETH MEES
EASTMAN KODAK COMPANY.

DR. MARTIN KNUDSEN
UNIVERSITY OF COPENHAGEN.

THE WATSON MEDAL AND THE PROMOTION OF ASTRONOMICAL RESEARCH

The James Craig Watson Medal and accompanying honorarium of $100 was



DR. ERNEST WILLIAM BROWN
YALE UNIVERSITY OBSERVATORY.

awarded to Dr. Ernest William Brown, of Yale University Observatory, New Haven, Conn., "in recognition of his outstanding contributions to astronomical science, mainly in the field of gravitational theory in the solar system."

Dr. A. O. Leuschner, chairman of the board of trustees of the Watson fund, which recommended the award of the James Craig Watson Medal to Dr. Brown, remarked in his presentation speech that

The problems of motion in the solar system have challenged the ingenuity of the greatest mathematicians and theoretical astronomers. Of those who have contributed to their solution none has attained the precision in representing the observed positions of the moon than Ernest W. Brown has achieved in his well-known theory. In 1907 he received the Gold Medal of the Royal Astronomical Society on the completion of the literal and numerical theory. At that time about a dozen lunar theories had been produced. Of these that of Hansen held its place in the nautical almanacs. Before Brown's theory could replace that of Hansen it was necessary for him to make his theory accessible in the form of tables. His tables have been uniformly used in the nautical almanacs since 1923 and predicted the 1923 eclipse with surprising accuracy. The honors which Brown has received were prompted not only by his lunar theory, although he had made it his principal task since 1890. At the same time his genius has conquered a variety of other hitherto unsolved problems based on Newton's Law of Gravitation. All these endeavors have led to new and significant results. The award of the Watson Medal therefore is based on his notable contributions to gravitational theory in general rather than on the specific achievement of the lunar theory.

The academy may justly be proud to count him among its members and to be able to honor him by the bestowal of the Watson Medal.

THE MARY CLARK THOMPSON MEDAL

The Mary Clark Thompson Medal and accompanying honorarium of $250 was awarded to Dr. Amadeus Grabau, of the National University of Peking, Peking, China, "in recognition of his long and distinguished record in paleontology and stratigraphic geology." Dr. Waldemar Lindgren, chairman of the committee on the Thompson fund which recommended the award to Dr. Grabau, emphasized in his presentation speech

DR. AMADEUS GRABAU
NATIONAL UNIVERSITY OF PEKING.

the distinguished services of Professor Grabau in general and stratigraphic geology, in the science of non-metallic mineral deposits, and particularly in paleontology. His paleontological researches cover the Paleozoic of New York, and during the last seventeen years the paleontology of China. The results of this work are contained in a splendid series of monographs on Chinese Paleozoic and also Mesozoic fossils, the last volume of which was published like the rest by the Academia Sinica, in Peking. His contributions are fundamental and exhaustive. And this in spite of severe physical handicaps during later years which would have discouraged any man with less courage and energy. Among his characteristics are an indomitable nature; a faculty of inspiring others with his enthusiasm; an ability to plan and carry out the work to which he has devoted his life.

In presenting this medal we are paying a just tribute to a most distinguished paleontologist and geologist who has brought honor to American geology to the four corners of the earth.

We regret deeply that Professor Grabau is unable to be here in person but rejoice that we may entrust the medal to Mrs. Grabau, who is here with us to-night and who will transmit the token to Professor Grabau with our admiring regards.

In the absence, in China, of Dr. Grabau, the medal was received by Mrs. Mary Antin Grabau on behalf of her husband. In the acceptance speech, prepared by Dr. Grabau and read by his wife, Dr. Grabau gave a brief summary of the work with which he has been identified in China during the past seventeen years and of the remarkable progress that has been made in recent years in geological and other scientific work in China. To quote from his speech:

The scientific study of natural history is now a recognized intellectual pursuit in China and those of us who were privileged to be present and in a measure give aid during the early years of development, feel confident that in the years to come geological, paleontological, biological and archeological contributions by Chinese naturalists will become of increasing importance, not only to their home country, but to the world of science at large.

Chinese naturalists feel as I do, that in honoring me to-night you are giving recognition to the progress of the scientific work in China, and they take it as an encouragement for the unabated continuance of their endeavors.

With this interpretation of your award to me of the Thompson Medal and with my sincere personal thanks, I accept the honor.

F. E. Wright,
Home Secretary

THE NEW BUILDING OF MELLON INSTITUTE

Mellon Institute of Industrial Research at Pittsburgh began a new phase of its career when its new building was dedicated in May as the principal event of a series which was attended by scientific and industrial leaders of this and other countries.

Dr. Edward R. Weidlein, director of Mellon Institute, presided at the formal dedication and addresses were given by Mr. Andrew W. Mellon and Mr. Richard K. Mellon, representing the founders. Other speakers were Dr. Irving Langmuir, Dr. Harold C. Urey and Dr. William P. Murphy, all of whom are Nobel laureates.

The new building is the third home of the institute, which started as a separate organization in a small frame building on the campus of the University of Pittsburgh twenty-six years ago. In 1915, the institute moved into its second home, the building recently vacated, in which it carried on the work which earned for it a national and international reputation.

Long before floor plans were drawn for the present edifice two fundamental requirements were established by the founders. First, the building must be the most advanced scientific workshop that modern knowledge could provide. Second, it must be beautiful as a tribute to science and to the institute's own achievements. From the outset, preference was weighted heavily in favor of the Grecian school of architecture, which combines beauty with the simplicity appropriate to a home of science.

In form, the structure is built as a hollow square, wider at the front than at the rear and with center and connecting wings in the shape of a cross. This ar-

rangement provides four interior courts which are the main natural light sources. The building is 306 feet wide at the front, 227 feet wide at the rear, and 334 feet from front to rear. Institute requirements made necessary a structure of about six and one-half million cubic feet —four times the amount of space in the previous building.

Many features of the new edifice derive from some of the finest examples of ancient Grecian architecture. Its façades are very nearly the same in proportion as the long lateral façades of the Parthenon at Athens. Other details were inspired by the temple of Nike Apteros on the Acropolis and the temple of Artemis in Sardis, Asia Minor. To many visitors the most impressive features of the exterior architecture are the beautiful limestone, monolithic columns, of which there are 62 in the four façades. As they came from the quarry the rough blocks each weighed approximately 125 tons, the finished columns weighing about 60 tons. These columns constitute the largest monolithic column installation in the world.

The building has nine stories, three of which are built below ground level. The main or fourth floor is occupied by the executive offices, general office and library. The three lower floors contain the various general service departments and the sections for large-scale experimentation. The fifth to eighth floors, inclusive, are given over to laboratories, while the ninth floor houses much of the ventilating apparatus. The major portion of the building is now finished, but certain portions have been held in reserve to provide for the installation of special facilities and research groupings. The finished portion has a total of 355 rooms.

The first floor contains equipment for supplying compressed air, vacuum, hot water and refrigerated drinking water as well as service equipment, such as air-conditioning machinery for the auditorium, the main switchboard, motor generator sets and the main plugboard for special currents. On this floor and other lower floors a large amount of space is provided for unit plant installations in individual rooms and especially in the large engineering laboratories, which

NEW BUILDING OF THE MELLON INSTITUTE.

A CORNER OF THE MAIN LOBBY

THE ROOM IS CARRIED OUT IN SIMPLE GREEK ARCHITECTURE. WALLS, CEILING AND FLOOR ARE OF BOTTICINO MARBLE, EXCEPT FOR THE THIN, DARK STRIPS OF NERO MARBLE WHICH ACCENT THE FLOOR. THE BAS-RELIEF OVER THE DOORWAY DEPICTS THE CREATION OF SCIENTIFIC KNOWLEDGE AND SYMBOLIZES THE WORK OF THE INSTITUTE.

occupy an L-shaped area two stories high. Here machinery and processes are developed and applied to translate laboratory methods into sub-commercial production.

On the second floor is the auditorium, which seats 350 persons and is completely equipped with motion pictures, stereopticon and amplifying equipment. Also located here are machine, woodworking, pipe, sheetmetal and electrical shops for service to all the fellowships, as well as a cold storage room, electric furnace room and the electrochemical laboratory.

Space for social and recreational activities has been provided on the third floor. Also on this floor are the building control room, the telephone switchboard, apparatus for the automatic telephone system, rooms for the storage of special instruments and apparatus, the photographic laboratories and other facilities. The library is the principal feature of the fourth floor. This beautiful room is finished entirely in Slavonian and English oak and has the style of the Renaissance, with influences from the works of Sir Christopher Wren and Grinling Gibbons and also from the Tirolese styles of the same period. It will accommodate a collection of 100,000 volumes.

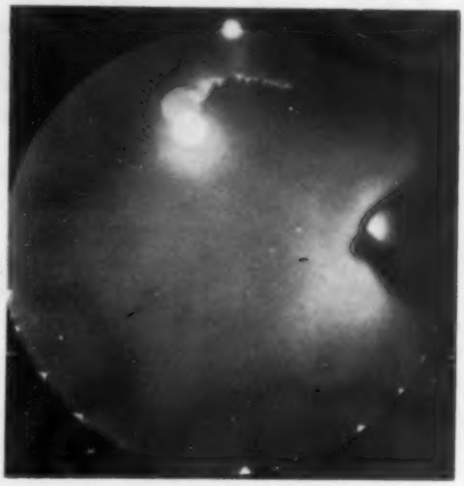
While each of the four upper laboratory floors has special rooms, most of the space is occupied by the two types of laboratories adopted as standard by the institute. The small laboratories are 12 feet by 19 feet in size and the large laboratories are 19 feet square. In design and equipment these laboratories represent the results of several years of experimental work by the institute's executive staff. In the laboratories and other parts of the building, many innovations were designed to meet the requirements of the institution, some of which are products of the institute.

J. D. U.

CHARTING THE NIGHT WIND

A PHOTOGRAPHIC method of charting the night winds high above the earth to determine direction and velocity for weather forecasting and aircraft operations has been worked out in the meteorological laboratory of the Massachusetts Institute of Technology by Athelstan F. Spilhaus, of the Woods Hole Oceanographic Institution.

The method makes use of a "whole sky camera," which has a 180-degree lens; a pilot balloon and magnesium flares attached at intervals to a length of ordinary blasting fuse. From an observation point on the earth the camera lens is pointed upward, and as the sounding balloon ascends the flashes of the magnesium flares, ignited at known intervals, are recorded on the plate. The photograph taken by the 180-degree camera is circular, the circumference depicting the horizon all around, and the brilliant magnesium flashes are registered on the plate regardless of the direction in which the balloon moves. Thus, by measuring the angles of elevation and direction between the camera station and the flashes, and correlating these data with the rate of ascent of the pilot balloon, an accurate record of the wind velocity and direction is obtained.



A RECORD OF THE NIGHT WINDS

IN THIS PHOTOGRAPH THE CIRCUMFERENCE OF THE CIRCLE IS THE HORIZON WITH THE CITY LIGHTS SPOTTED ALONG ITS EDGE, WHILE THE ZENITH, DIRECTLY OVERHEAD, IS IN THE CENTER OF THE CIRCLE. THE WHITE SPOT AT THE TOP IS TO MARK TRUE SOUTH AND BELOW IT ARE A SERIES OF 18 MAGNESIUM FLASHES INDICATING THE COURSE OF A PILOT BALLOON. BY MEASURING THE ANGLES BETWEEN THE CAMERA AND THE VARIOUS POSITIONS OF THE FLASHES, WIND DIRECTION AND VELOCITY ARE OBTAINED. THE FAINTEST FLASH WAS TAKEN AT A DISTANCE OF SEVEN MILES WHEN THE BALLOON HAD REACHED AN ALTITUDE OF 13,000 FEET. AT THE RIGHT IS THE MOON, WHICH WAS SHADOWED FOR PART OF THE EXPOSURE BY THE PHOTOGRAPHER.

EQUIPMENT FOR STUDYING THE NIGHT WINDS

THE APPARATUS CONSISTS OF A SOUNDING BALLOON, A LENGTH OF FUSE, ALONG WHICH ARE ATTACHED MAGNESIUM FLARES, AND A 180-DEGREE CAMERA. THE LATTER IS MADE UP OF A LARGE LENS BARREL AND SHUTTER, AND A PLATEHOLDER.

The usual method of measuring winds of the upper atmosphere, which often blow in the opposite direction to the surface winds, is to release a hydrogen-filled pilot balloon and follow its course by

means of a theodolite on which the angles of elevation and direction are read every half minute or minute. At night it has been the practice to suspend a paper lantern containing a candle from the balloon and to train a theodolite on the light. The disadvantages of this method, however, are that the light is extremely dim and is frequently lost in a short time. Observers have also been known to confuse the faint light of the lantern with stars. The Spilhaus method makes it possible to take readings photographically at very brief intervals, and the apparatus may be used by inexperienced observers. All that is necessary is to open the shutter of the camera and release the sounding balloon after lighting the fuse to which the magnesium flares are re attached for any desired flash interval. Tests of the new method have been carried on for several weeks through the cooperation of the new Dewey-Almy Chemical Company, which supplied a new type of sounding balloon. Test plates for recording the magnesium flashes at distances of as much as seven miles and at heights of over 13,000 feet have been made. It is expected that this distance and height can be greatly exceeded.

In the field of meteorological research the Spilhaus method of nocturnal soundings will provide a means of making detailed studies of the structure of the winds. The intervals of observation can be reduced to five seconds for such investigations, an interval far too brief for theodolite observations.

J. J. R.

THE TAKIN GROUP AT THE PHILADELPHIA ACADEMY

THE habitat group of takin from Western China, opened in the Free Natural History Museum of the Academy of Natural Sciences of Philadelphia, is the first of its kind to be exhibited anywhere, and shows these rare and strange-looking animals in an unusually attractive setting, quite different from any of the other large groups in the museum. Flanked by huge blooming rhododendron bushes such as abound in the mountains of Sze-Chwan, where Brooke Dolan, II, secured the specimens on an academy expedition to that far region near the Tibetan bor-

THE HABITAT GROUP OF TAKIN.

der, four of these cattle-like mountain antelopes are shown near a stream, with mist-veiled rugged heights in the background.

First mentioned some 600 years ago by the famed Venetian traveler, Marco Polo, who described them only as "very wild, fierce animals," the takin remained a mystery until native Chinese hunters brought a specimen to L'Abbe David in 1869, since when occasional explorers have recorded it. Now, for the first time, it is shown as if alive in its almost inaccessible native haunts—a large bull, two cows and a calf grouped in life-like attitudes.

These curious beasts, with shaggy coats of mingled brown and buff color and short curved horns, live at altitudes of 7,000 to 16,000 feet, in the dense bamboo and rhododendron thickets. Though larger than the Rocky Mountain goat which is found in the Western United States, British Columbia and in Alaska, they probably are related to this animal. Despite their bulk, they can get over rough ground at an amazing rate, and this makes them difficult to approach. They possess great strength, and the natives regard them with considerable awe.

These awkward-looking, rather clumsily built animals travel in small herds, each of which follows an old bull as its acknowledged leader. To such a pitch is this blind obedience carried that one native hunter has reported that when he shot a leader, which then fell over a high cliff, the rest of the herd immediately leaped into the ravine.

This new group represents the latest development in museum exhibits of this nature. All the artificial accessories, including the remarkably realistic rhododendron blossoms, were made in the academy's Department of Museum Exhibits, and the group was erected under the direction of Harold T. Green, curator of that department. The background was painted by C. Clarke Rosenkranz, and the animals were mounted by Louis Jonas.

L. M. H.

THE SIZE OF ATOMIC NUCLEI

Of all the domains which the mind of man has to contemplate, the nucleus of the atom is the smallest. It is at least a thousandfold smaller than the sizes we usually ascribe to the atom itself and, indeed, if all the nuclei in the world were placed in contact with one another, their smallness is such that the earth could go inside an ordinary sized room. The study of the size, or more definitely the radius, of the nucleus of atoms has, however, been rather disappointing up to the present time. Various methods of estimating nuclear radii have been devised, none of which was extremely precise, but which showed that a general law governed the size of a nucleus, which can briefly be stated. This law is "the volume of a nucleus is proportional to the number of particles in it." In less colloquial terms the radius of a nucleus is proportional to the cube root of its atomic weight.

So simple a rule as this could have been guessed easily by any one and therein lies the disappointing nature of the study of the nuclear radius, for the conclusions we reach substantiate a law which needs only the most general ideas for a foundation. If, however, definite exceptions to this simple rule could be found, we should have a chance to use these exceptions to tell us more intimate facts about the nature of the nucleus. Recently such an exception has been found. In work at Yale by the writer, H. L. Schultz and Gordon Brubaker, the transmutation of argon into calcium has been observed and studied with striking results. A helium nucleus, or alpha particle, is fired into an argon nucleus and is caught by it to form an unstable conglomerate which breaks up into calcium and a neutron, which last can be detected by the apparatus. The interest lies in how the

reaction proceeds as the energy of the incoming alpha particles is changed. A nucleus acts in many ways like a volcano and crater as far as its behavior to incident nuclei is concerned—that is, it repels them until a certain distance is reached and then attracts. In terms of the volcano the crater can not be reached until enough energy has been spent to reach the top and then it is all too easy to fall inside. By studying the energy at which the transmutation takes place readily the height of the volcano (or potential barrier) and the radius of the crater (or nuclear radius) can be found. For argon it is found that the nuclear radius is nearly 30 per cent. larger than expected, so that its volume is double the normal value. This means that argon does not fit into the accepted scheme, and thus revives hope that the study of nuclear radii may help us to gain information about the inside structure of the nucleus. This is, the writer considers, the most important result achieved.

Some further results have been obtained which lend themselves to speculation. At the same time as the argon reaction was discovered a similar transmutation of chlorine into potassium was achieved and a study of the volcano and crater made. A much smaller radius was found, though not quite as small as would be expected, so that again an interesting anomaly is found. Now the resulting potassium is of a radioactive form which has been known for some time. Its radioactivity has been difficult to explain, for the radioactive process took place with a considerable energy liberation and would normally have proceeded very rapidly. Actually it proceeds extremely slowly. Why? One possible explanation is that the potassium nucleus has a rapid rate of rotation which has to be changed in its radioactive process. This change is so great that it slows down the radioactivity enormously and gives radiopotassium its unusually long life. It seems to the writer that if we assume that chlorine, too, has a rather large radius (close to that of argon, which is its neighboring element) but that the helium projectiles have to supply additional energy to create the rapidly spinning potassium nucleus, then the apparently smaller radius for chlorine can be explained and also the long lifetime of potassium. While calculations seem to bear out the truth of these ideas, this suggestion must still be considered as speculation. As time passes and more exact experimenting is completed, the idea can be checked.

ERNEST POLLARD

YALE UNIVERSITY

WHY WE DO IT

An Elementary Discussion of Human Conduct and Related Physiology

By EDWARD C. MASON, M.D., Ph.D., F.A.C.P.
Professor of Physiology,
University of Oklahoma School of Medicine, Oklahoma City

177 Pages, Illustrated. With special jacket. Price, $1.50

IN "Why We Do It" the author has presented a convincing argument which supports the contention that the child is both egocentric and narcissistic and necessarily considers itself to be the center of the universe. It is from this center that it constructs its conception of the universe. Our problem is to develop the child's intellectual potentialities and transform it into an emotionally mature adult. If we are successful the individual is then able to meet the problems of life directly and efficiently; he will deal in reality and will not resort to the fantasy practiced by the neurotic or regress to the prelogical state of the psychotic.

IN "Why We Do It" we find that regardless of what we consider the child to be, the problem of civilization is one of transforming the raw material of the newborn baby into a "refined" product acceptable to society. At the same time the child is faced with the problem of accepting the demands of civilization without the privilege of modifying it to meet his demands. The degree of success of the transformation varies with each "barbarian" born and approximately only 50 per cent are able to make an adjustment satisfactory to society and to themselves. The author explains the mechanism of the transformation and how parents and teachers may aid in the process.

IN "Why We Do It" the author states, "The absolute goal of all human beings is to satisfactorily meet their environment. The means employed and the end gained in achieving such satisfaction vary with each individual. As an example, the insane individual employs certain means with which to meet his environment and, thereby, accomplishes the task to his own satisfaction. It is true that the means used and the end gained do not meet our accepted social standards." He compares and contrasts the different methods used by the "normal," the "neurotic" and the "psychotic" when meeting their environment, specially stressing the importance of emotional maturity.

THE C. V. MOSBY COMPANY, 3525 Pine Blvd., St. Louis, Mo. (Scientific Monthly)

Gentlemen: Send me a copy of the new book—"Why We Do It" by E. C. Mason. ☐ Send bill with book.

☐ I enclose check or money order for $1.50.

Dr. .... Address ....